# Chapter 2. Environmental Setting

## Physiography and Geomorphology

### Regional Physiography

Kelleys Island, the largest of the Ohio islands in western Lake Erie, lies in the Central Lowlands physiographic province (Fenneman 1938), which encompasses all of Lake Erie. Relatively narrow and shallow, Lake Erie is the 4th largest of the Great Lakes by surface area at 9,910 $mi^2$ (25,700 $km^2$) and smallest by volume at 116 $mi^3$ (484 $km^3$). The lake is oriented with its long axis in an east-northeast direction and is naturally divided into three basins: western, central, and eastern (Bolsenga and Herdendorf 1993, Fuller et al. 1995).

The western basin, lying west of a line from the tip of Point Pelee, Ontario to Cedar Point, Ohio is the smallest and shallowest basin with most of its bottom depths between 26 and 36 ft (8 and 11 m). In contrast with the other basins, a number of bedrock islands and shoals are situated in the western basin (Figure 2-1), which form a partial divide between it and the central basin. The western basin bottom is flat except for the steep-sided islands and shoals. The deepest soundings are 62 ft (19 m) in a small depression north of Starve Island Reef and 54 ft (16.5 m) north of Kelleys Island (Lewis and Herdendorf 1976). The central basin has an average depth of 62 ft (19 m) and a maximum depth of 85 ft (26 m). Except for the rising slopes of a relatively shallow sand and gravel bar (glacial moraine) between Erie, Pennsylvania and the base of Long Point, Ontario, the bottom of this basin is extremely flat. In contrast, east of this separating bar, the eastern basin is relatively deep and bowl-shaped. A considerable area of the eastern basin lies below 120 ft (37 m) and the deepest sounding of 210 ft (64 m) is about 8 mi (13 km) east-southeast of the tip of Long Point, Ontario.

The varying depths of the Lake Erie basins are attributed to differential erosion by preglacial streams, glaciers, and postglacial lacustrine processes. Lake Ontario is separated from Lake Erie by the resistant Silurian limestones and dolomites of the Niagara Escarpment, whereas the central and eastern basins of Lake Erie are underlain by nonresistant shale, shaly limestone, and shaly sandstone of Late Devonian age that dip gently to the southeast. The southward advance of Pleistocene glacial ice was obstructed by the Mississippian Escarpment along the southern edge of these basins and the ice was directed westward along the outcrop of the softer Upper Devonian shales. These shales were deeply eroded to form the narrow eastern basin. Farther west, where the dip of the beds is less and the width of the soft shale belt is greater, glacial erosion resulted in the broader, but shallower, central basin (Carman 1946:279-283).

The bottom sediments of Lake Erie consist of silt and clay muds, sand and gravel, peat, compact glaciolacustrine clays, glacial till, shoals of limestone and dolomite bedrock and rubble, shale bedrock shelves, and erratic cobbles and boulders composed chiefly of igneous and metamorphic rocks. The distribution of bottom sediments is related to the bottom topography. The broad, flat areas of the western and central basins, and the deep areas of the eastern basin have mud bottoms (Pegrum 1929). Midlake bars and nearshore slopes are comprised mostly of sand and gravel or glacial till. Rock is exposed in the shoals of western Lake Erie and along the shores of the eastern basin. Littoral currents have concentrated sand in spits and baymouth bars at such places as Point Pelee, Pte. aux Pins, and Long Point, Ontario; North Cape, Michigan; East Harbor, Cedar Point, and North Bay of Kelleys Island, Ohio; and Presque Isle, Pennsylvania. The natural outlet for Lake Erie is the Niagara River, which has a length of 37 mi (60 km) and drops a total of 324 ft (99 m) to Lake Ontario. Navigation to the east of Lake Erie is afforded via the Welland Canal and the New York State Barge Canal (Erie Canal) and to the west via the Detroit River.

### Kelleys Island Geomorphology

Kelleys Island lies in western Lake Erie, 3.5 mi (5.6 km) off the Ohio mainland at Marblehead Peninsula and 9 mi (14.5 km) north of Sandusky. With an area of 4.37 $mi^2$ (11.32 $km^2$) and a total shore length of 11.4 mi (18.3 km), it is the largest American island in Lake Erie (Cooper and Herdendorf 1977:2). The

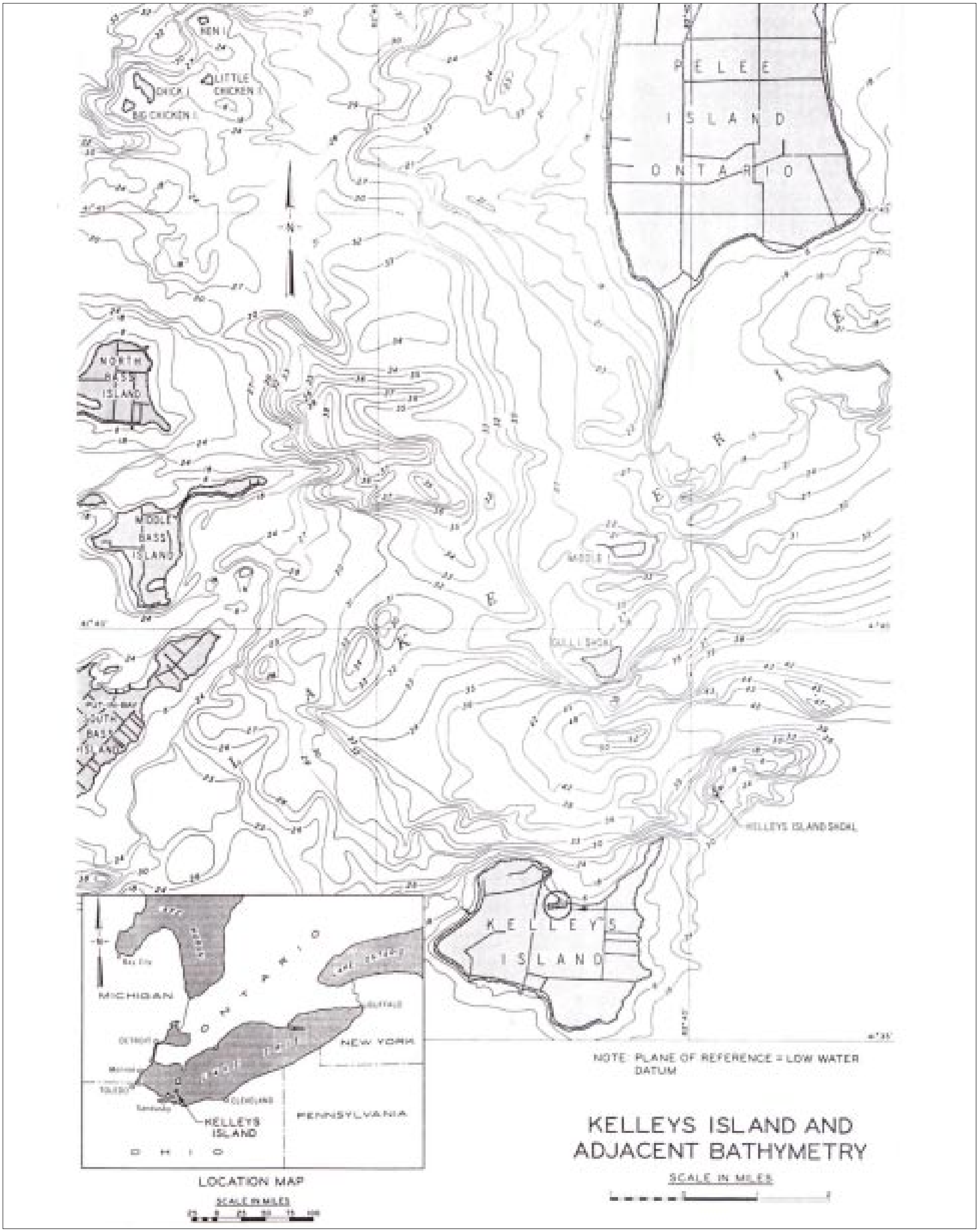


*Figure 2-1. Bathymetric map of Lake Erie to the north of Kelleys Island, showing numerous reefs and shoals; arrow points to a State of Ohio harbor of refuge proposed for North Pond (after Wilson and Hudson 1963:plate 1).*

island's maximum elevation is located near the southwestern shore; at 631 ft (192 m) above mean sea level (MLS) it is about 60 ft (18 m) above the level of Lake Erie (Figure 2-2).

The island's limestone quarries have long been known to science because of their remarkable glacial grooves (Figure 2-3) carved in the surface of the Columbus Limestone and the well-preserved fossil fauna (Bowe 1985, Bowe and Herdendorf 1990). For decades high-quality building stone, lime, and crushed rock were produced from these quarries (Stauffer 1909:136). Columbus Limestone (Middle Devonian age) bedrock underlies the major portion of Kelleys Island. A thin layer of glacial drift and soil covers this formation. Rock outcrops are common, particularly along the shores. Outcrops are of two types: (1) broad shelf areas with gentle dip slopes, common along the south and east shores and (2) vertical to overhanging cliffs up to 25 ft (8 m) high, especially along the north and west shores (Fisher 1922:7). Uplift in the bedrock west of the Bass Islands, known as the Cincinnati Arch, gives the rock formations of western Lake Erie a regional dip toward the southeast. As a result, most of the islands of western Lake Erie have a *cuesta* or hogback shape (Figure 2-4) with steep cliffs on the side toward the arch and gentle, shoaling coasts away from the arch (Carman 1946:282).

### Lake Erie Bathymetry

The north shore of Kelleys Island is characterized by: (1) a broad headland on the west with a relatively steep offshore slope, (2) a large relatively shallow embayment, known as North Bay, in the central portion, which extends inland in the form of the sand bar enclosed North Pond, and (3) an elongated peninsula known as Long Point, with a bottom intermediate to the other two segments. The project area is located midway along Long Point where a


*Figure 2-2. Topographic map of Kelleys Island, showing project location (U.S. Geological Survey, Kelleys Island Quadrangle, 1979).*

*Figure 2-3. Aerial view of abandoned North Bay quarry, showing excavated glacial grooves at left center, ca. 1971 (photo by Tom Root, courtesy Ohio Historical Society).*

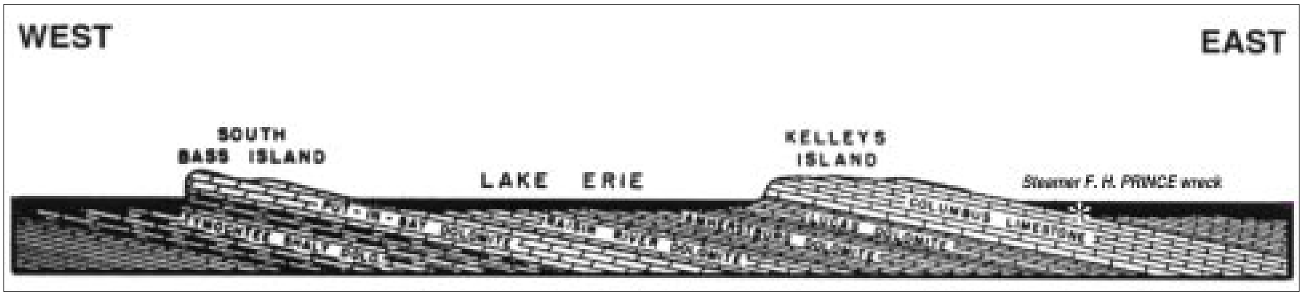


*Figure 2-4. Geological cross-section through the islands of western Lake Erie, showing bedrock formations and cuesta-shape of the islands (modified from Carman 1946:282).*

constriction in the point creates a gentle embayment (Figure 2-5). The shoreline varies from a sand-like substrate consisting of crushed mussel shells, to limestone cobble beaches, and to large car-sized slabs of limestone and exposed limestone bedrock planes.

The nearshore bathymetry of Lake Erie at the project site is shown on Figure 2-6. At the southerly end of the Predevelopment, Ltd. property, the bottom slopes lakeward at a rate of 6.1 ft (9.1 m) in depth per 100 ft (30 m) offshore. Midway along the shore in a sandy cove, the slope decreases to 4/100 and at the rocky headland at the northern end of the tract, the slope increases to 8.4 /100. Farther offshore the slope is gentler, averaging about 1.6/100 out to the 18 ft (5.5 m) depth contour, at about 750 ft (230 m) offshore. At 2,750 ft (840 m) offshore the bottom reaches a depth of 30 ft (9 m), yielding an overall gradient of 1.1/100.

The bottom depths offshore of the project property range from nil at the shoreline of Kelleys Island to 54 ft (16.5 m) below Low Water Datum (LWD) in a narrow depression south of Gull Island Shoal. Away from the island and shoals, depths generally range from 30 to 40 ft (9 to 12 m). Middle Passage, with a minimum depth of 25 ft (7.6 m), traverses the island chain east–west between Kelleys Island and Gull Island Shoal. Similarly, South Passage with a minimum depth of 15 ft (4.6 m) passes east–west between Kelleys Island and the mainland (Marblehead Peninsula). East of Kelleys Island, the depths are generally greater than 40 ft (12 m) as the bottom gently drops off into central Lake Erie.

The lake bottom surrounding Kelleys Island is dotted with bedrock reefs and shoals. By way of a formal definition, such features are elevations of rock, either broken or in place, or gravel shown on current NOAA navigation charts to be above the common level

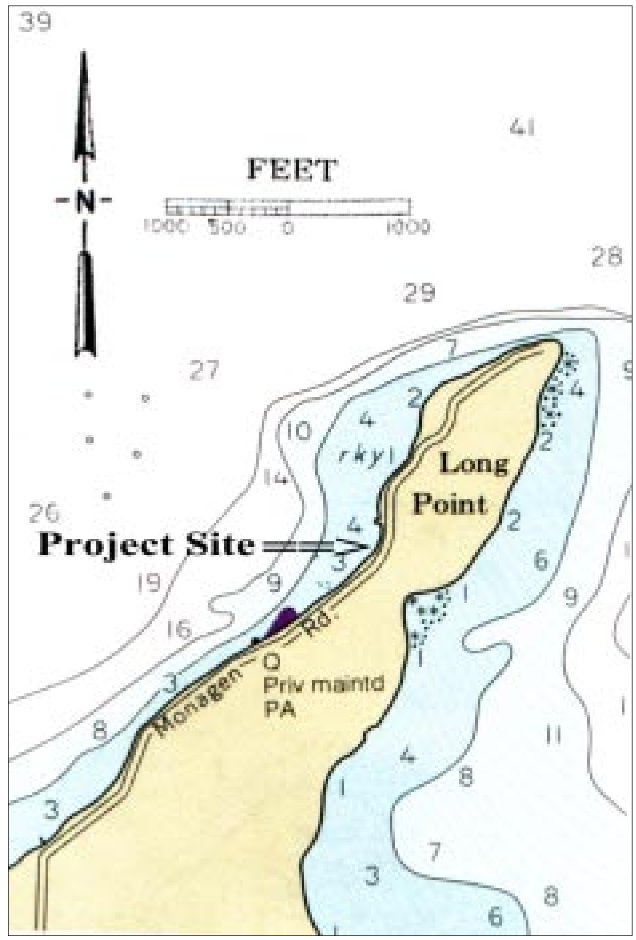


*Figure 2-5. Portion of a bathymetric chart of Lake Erie at Long Point on Kelleys Island, showing a constriction midway up the point and the embayment at the project site (NOAA Chart No. 14842, May 1986).*

of the surrounding bottom. In most cases these reefs also qualify as "coral reefs"—albeit fossil ones—in that they were formed by Cnidarian organisms some 380 million years ago. The offshore reefs and the abandoned quarries are excellent sites for fossil collecting and have yielded over 70 species of Devonian marine organisms (Stauffer 1909, Bowe 1985, Feldmann and Hackathorn 1996).

Seven of the reefs and shoals surrounding Kelleys Island have been given formal names (Table 2-1) and three of them have been surveyed in detail (Gull Island Shoal, Kelleys Island Shoal, and Middle Passage Reef). Maps of these reefs have been published by the Ohio Department of Natural Resources, Division of Geological Survey (Herdendorf and Braidech 1972) and Sportsman's Connection (Billig 2001). Most of

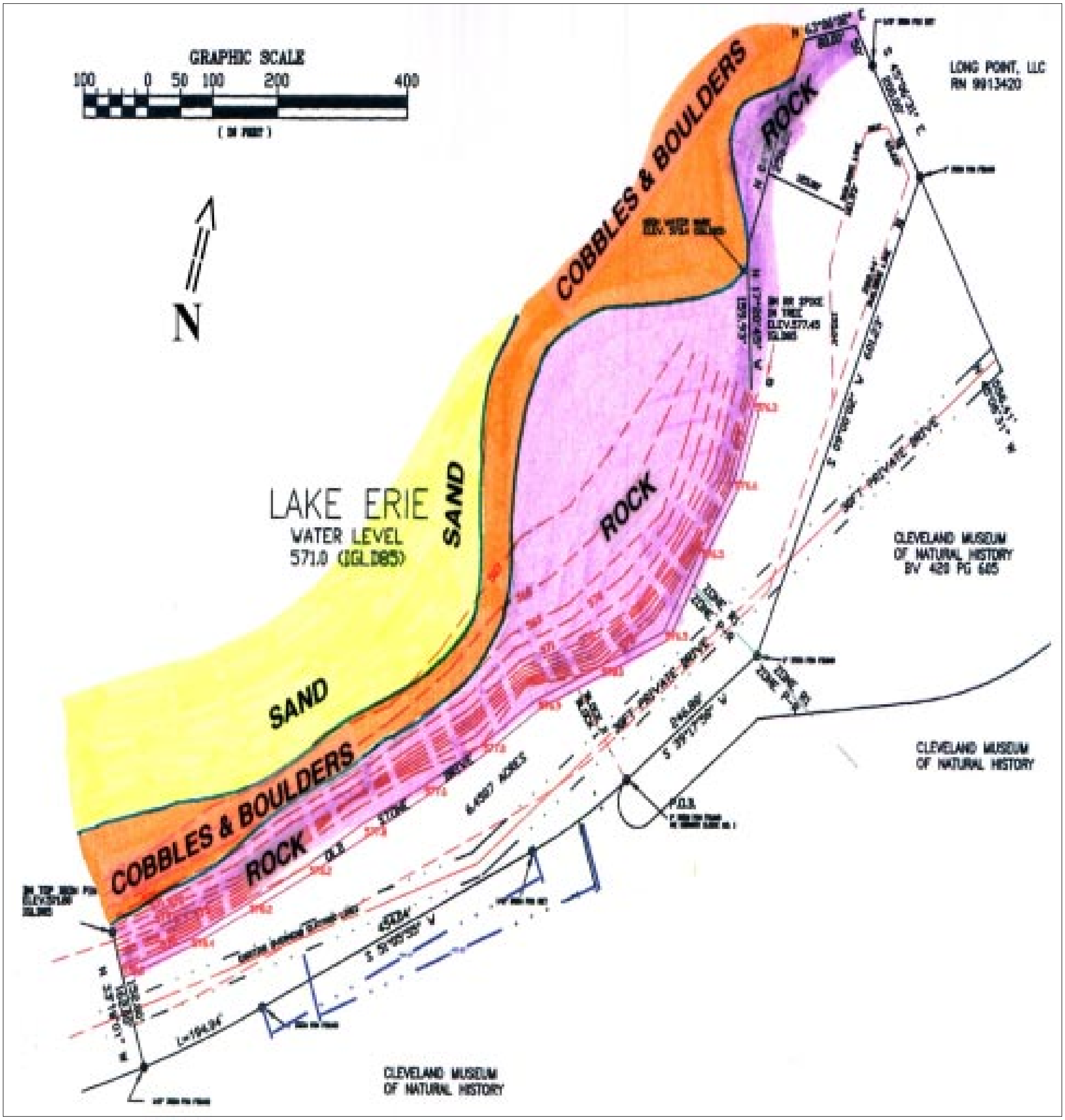


*Figure 2-6. Map of the nearshore area at the project location, showing bottom contours and composition.*

**TABLE 2-1. REEF, SHOALS, AND DEEP NEAR KELLEYS ISLAND**

| REEFS & SHOALS | Least depth (ft) | (m) | Area (acres) | (ha) | Latitude (crest) | Longitude (crest) |
|---|---|---|---|---|---|---|
| American Eagle Shoal | 10 | 3.0 | 135 | 55 | 41°36'00"N | 82°46'00"W |
| Airport Reef | 24 | 7.3 | 15 | 6 | 41°35'35"N | 82°39'41"W |
| Carpenter Point Reef | 12 | 3.7 | 33 | 13 | 41°36'18"N | 82°44'42"W |
| Gull Island Shoal | +1 | +0.3 | 432 | 175 | 41°39'33"N | 82°42'22"W |
| Kelleys Island Shoal | 2 | 0.6 | 470 | 190 | 41°38'20"N | 82°38'24"W |
| Middle Passage Reef | 23 | 7.0 | 110 | 45 | 41°39'16"N | 82°41'41"W |
| South Shoal | 15 | 4.6 | 56 | 23 | 41°35'44"N | 82°46'55"W |

| DEEP | Least depth (ft) | (m) | Area (acres) | (ha) | Latitude (bottom) | Longitude (bottom) |
|---|---|---|---|---|---|---|
| Gull Island Deep | 54 | 16.5 | 390 | 158 | 41°38'38"N | 82°41'30"W |

Note:
Depths below Low Water Datum for Lake Erie: elev. 569.2 ft or 173.49 m (IGLD, 1985).

the reefs are conical in shape and elongate, as is Kelleys Island, in a NE-SW direction. Two factors have influenced this elongation: (1) vertical joint systems in the bedrock oriented parallel to the elongation and (2) northeast to southwest movements of glacial ice as inferred from grooves, striations and scour marks cut into the bedrock of the island and lakefloor (Hartley 1962).

Typically the reefs and shoals consist of limestone or dolomite bedrock and associated rock rubble and gravel. The topography of their tops ranges from rugged surfaces caused by bedrock pinnacles and large boulders to smooth slabs of horizontally bedded rock. In places the submerged bedrock has the appearance of a set of low stairs, with the steps dipping slightly to the east from the crest to the fringe of the reef. Because the bedrock is calcareous ($CaCO_3$), and therefore susceptible to solutioning, many cavities (0.25- to 0.75-in or 0.64- to 1.90-cm diameter) have formed on the rock surface. These cavities are often sites of fish egg deposition, particularly by walleye. The bedrock cores of some of the reefs and shoals are masked by rubble composed of the local bedrock and glacial erratics transported by the ice sheets. The rubble can range from small pebbles to boulders over 5 ft (1.5 m) in diameter. On the upper portions of the reefs and shoals, isolated patches of sand and gravel commonly fill joint cracks and shallow depressions in the rock; at the fringes sand and gravel or glacial till clay lap over the rock. Wave action is generally sufficient to sweep the reef tops free of silt and clay deposits, except during periods of prolonged quiescence. Research diver observations for the two largest shoals, Gull Island and Kelleys Island, are reported by Herdendorf (1985:158).

## GEOLOGY

### BEDROCK GEOLOGY

Lake Erie is underlain by middle Paleozoic sedimentary rocks deposited some 450 to 350 million years ago (Herdendorf 1989). These rocks are composed of limestones, dolomites, shales, and sandstone that form bedrock outcrops on the lake floor. At the time when these rocks were being deposited as soft sediments in a tropical sea, the area we now know as Ohio was then located about 20° south of the equator, near the latitude of present day Tahiti. The depositional environments ranged from a tropical barrier reef habitat at the beginning of this interval to deltas and black muddy bottoms at the end, as mountain building episodes to the east (the result of tectonic plate collisions) delivered sands and silts to the sea. Regional uplift following these episodes initiated a long period of erosion, which resulted in the excavation of a major stream system down the long axis of the present lake. Ice sheets of the Pleistocene continental glaciers further sculptured this valley system by riding up over the

Niagara Escarpment and excavating most deeply in the eastern end of the lake, moderately deep in the central portion, and least deeply over the limestone bedrock at the western end of the lake, forming the distinctive three basins that characterize Lake Erie. This process created the impressive glacial grooves of Kelleys Island.

The bedrock in the islands area of western Lake Erie was deposited as lime muds in shallow, warm Silurian and Devonian seas, that covered the region some 400 million years ago. These deposits were later consolidated into dense limestone bedrock. The warm, clear conditions of the Devonian seas can be inferred from the abundant fossil corals and other invertebrates found in the rocks on Kelleys Island. The existence of evaporite beds, such as halite (rock salt) and gypsum, indicate that several isolated basins also occurred at this time interval. Enclosed by barrier reefs, the waters were repeatedly evaporated to form the massive salt deposits. Gypsum beds have been quarried at the surface near Port Clinton, while halite deposits are currently being mined 2,000 ft (600 m) below the lake bottom at Cleveland. Although these beds were deposited at approximately the same time and at the same elevation, the collision of tectonic plates to the east tilted the beds so that they now dip to the east-southeast at a rate of about 30 ft/mi (6 m/km).

While a shallow Devonian sea occupied the Kelleys Island area, the Appalachian Mountains were being built to the east. The collision of the northwest coast of Africa with the east coast of North America caused the sediments in the Appalachian trough (ancestral Atlantic Ocean) to be folded into a formidable mountain chain, which had consequences all the way to the Lake Erie islands. Erosion of these newly formed mountains resulted in the deposition of sediments which are now the shales and sandstones that cover the limestones east of the islands. The turbid water associated with this deposition brought an end to the clear environment required to sustain coral reefs. The result of folding can also be observed at Kelleys Island and many of the other islands in western Lake Erie. An uplifted fold in western Ohio, known as the Cincinnati Arch, gives the rock formations of the islands their eastward dip. Consequently, the islands have steep cliffs on the side toward the arch and a gentle shelf away from the arch (Figure 2-4). Kelleys Island exhibits this with high cliffs and deep water along its northwest shore and broad shelves along its eastern shore. To a lesser degree, the western and eastern shore of Long Point show this same phenomenon.

Two limestone formations are exposed on Kelleys Island and in the nearshore waters and reefs surrounding the island. Columbus Limestone underlies the major portion of the island and consists of light-gray to buff colored, fossiliferous beds that are moderately thin bedded near the surface and massively bedded below 10 ft (3 m). This erosion-resistant rock forms a chain of headlands and islands that traverses western Lake Erie from north to south—Marblehead Peninsula, Kelleys Island, Middle Island, and Pelee Island. This formation has been quarried extensively for building stone, lime, and crushed stone. Starting in the 1830s, these products have been transported from Kelleys Island by sailing vessels and steamers, several of which have wrecked near the shore or on the reefs and shoals surrounding the island.

Columbus Limestone consists of three lithologic units on Kelleys Island: (1) a basal, thick-bedded, magnesium limestone, (2) a middle layer of cherty limestone, and (3) an upper sequence of thin-bedded highly calcareous limestone (Fisher 1922:9). The basal beds are well exposed in the North Bay and South Side quarries where they present a massive, vertical face of grayish-brown fossiliferous limestone, 22 ft (6.7 m) thick. The cherty layer is about 3.8 ft (1.2 m) thick in the North Bay quarry walls and contains numerous, rather soft, gray to white chert nodules intermixed with brown limestone (Stauffer 1909:139). The upper 25-ft (7.6-m) thick beds are bluish-gray and the purest part of the formation. The top 10 ft (3 m) of this upper sequence splits into thin slabs (1 to 3 in or 2.5 to 7.5 cm thick) on weathering and contains extensive layers of brachiopod fossils, especially *Spirifer acuminatus*. These slabs were used by early settlers to build foundations and stone walls.The next 7 ft (2.1 m) down is also very fossiliferous, but somewhat more massive in character, while the bottom 8 ft (2.4 m) of the upper unit is a massive layer of gray to brown limestone known to the quarrymen as “bottom rock” because it formed the floor of most of the quarries (Stauffer 1909:136-142; Fisher 1922:9, 21-23).

Crushed flux stone requires a fairly high content of calcium carbonate and a correspondingly low amount of silica and alumina, while a higher content of magnesium carbonate can be tolerated for stone burnt for lime (Fisher 1922:21). The following analyses were performed by the Ohio Geological Survey (Lord 1884:534; Orton 1888:753) in the 1880s on Kelleys Island stone destined for these two purposes:

| Component | Flux stone for iron smelting | Stone to be burnt for lime |
|---|---|---|
| silica | 1.81% | 1.65% |
| alumina and iron | 0.75% | 0.14% |
| calcium carbonate | 87.50% | 77.22% |
| magnesium carbonate | 9.75% | 20.19% |
| residue | 0.19% | 0.80% |

The upper part of the Columbus Limestone is a very pure limestone and therefore was valuable for use as lime and flux. Analyses indicate increasing proportions of magnesium carbonate ($MgCO_3$) and decreasing portions of calcium carbonate ($CaCO_3$) from the top to the bottom. In the upper beds the amount of $CaCO_3$ was as high as 97% and the amount of $MgCO_3$ was as low as 2.7%, whereas the lower massive beds ran as low as 78% $CaCO_3$ and as high as 20% $MgCO_3$. Alumina, iron oxide, and silica made up the remainder (Ver Steeg and Yunck 1935:431). The lower, more massive beds best served dimension and building stone needs.

Lucas Dolomite, which underlies the Columbus Limestone, is exposed in the west shore bluffs and at the bottom of the deepest quarries. The rocks of this formation are gray to a drab in color, much less fossiliferous, and high enough in magnesium to be classified as dolomite. This formation and the Amherstberg and Raisin River Dolomites beneath it, are less resistant to erosion which accounts for the lack of islands and the 30-ft (9-m) deep swale between Kelleys Island and the Bass islands. Thus, Kelleys Island is the remnant of a Devonian limestone reef that once formed a divide between preglacial valleys. The relatively deep water north of Kelleys Island appears to be near the junction of several preglacial streams that had cut deeply into the bedrock.

## Glacial Geology

The most resent glacial advance (Wisconsinan) extended as far south as the Ohio River (about 18,000 years ago), and as the ice mass receded in pulses, moraines were deposited south of the present lake and at least two prominent end moraines were formed near the junctions of the lake's three basins. As the ice melted back into northern Ohio, large glacial lakes were formed between the moraines and the ice front. As the ice progressively retreated, new and lower outlets were uncovered and new lake stages were formed at successively lower elevations except were minor readvances of the ice temporally reversed this trend. Massive sand ridges and dunes were deposited along each of these shores and thick glaciolacustrine sediments were deposited in the lakes.

## Evolution of Lake Erie

When the last glacier retreated from the Niagara Escarpment and the Niagara River outlet was finally opened, but greatly depressed by the weight of the ice, much of the lake drained and smaller lakes were present only in the eastern and central basins. Isostatic rebound eventually brought the lake to near is present level about 3,000 years ago (Holcombe et al. 2003:700) and the present shoreline landforms, including islands, embayments, estuaries, beaches, bluffs, dunes, spits, and barrier bars then began to form. Lake processes and erosion continue to modify these landforms, often resulting in dramatic changes during violent storms. The existence of a boulder and cobble storm berm along both shores of Long Point, some 5 to 8 ft (1.5 to 2.5 m) above lake level, is evidence of this process (Figure 2-7).

**Early Lake Erie (12,400 to 8,000 YBP).** The glacial lake stages in the Lake Erie basin ended when the ice margin retreated sufficiently to the east to allow the lake level to be controlled by the sill at the Niagara Escarpment. This removed direct glacial influence in the Lake Erie basin and initiated the present lake. Forsyth (1973) described a catastrophic flood of water over the escarpment that incised a channel in the moraines and bedrock, resulting in a low water stage in the Lake Erie basin. The Niagara threshold, still depressed by glacial loading, was 82 to 100 ft (25 to 30 m) below the present Lake Erie level. Hartley (1958) presented a compelling argument for a low stage at 82 ft (25 m) below the current level, based on field evidence; while Coakley and Lewis (1985) used radiocarbon dates and contours on the glacial till surface to show a minimum level at least 100 ft (30 m) below the present lake level. Known as Early Lake Erie, this low stage had an elevation of about 490 ft (149 m) and a surface area of approximately 4,325 mi$^2$ (11,200 km$^2$). The evolution of Lake Erie from this low water stage to its present level involves glacio-isostatic rebound, changes in discharge waters to the lake, and climatic fluctuations.

*Figure 2-7. Storm berm along the southeast shore of Long Point (April 30, 2004).*

Initially, Early Lake Erie received discharge from Early Lake Algonquin (Lake Huron basin) via the newly formed St. Clair River-Lake St. Clair-Detroit River system (Calkin and Feenstra 1985), forming a small lake in the eastern basin. By 10,400 YBP Early Lake Erie (Figure 2-8) may have consisted of: (1) a marshy western basin through which an extension of this river system flowed via Pelee Passage (Hobson et al. 1969, Herdendorf and Braidech 1972), (2) a shallow central basin lake that flowed to the east via a channel cut through the Norfolk moraine (Long Point-Erie Ridge), and (3) a deeper eastern basin lake which drained to the east over the Niagara Escarpment. Differential glacio-isostatic uplift of the Niagara River outlet was rapid from about 12,400 to 10,400 YBP, at over 6.5 ft/century (2 m/century), followed by a slowing of the uplift rate to less than 3 ft/century (1 m/century) from 9,000 to 8,000 YBP (Coakley and Lewis 1985). Early in this period, about 10,300 YBP, flow into the western basin was interrupted when the Kirkfield outlet for Lake Algonquin (Lake Huron basin) was opened to Lake Iroquois (Lake Ontario basin) by deglaciation, which lowered the level in the Lake Huron basin and stopped drainage to Early Lake Erie (Kaszycki 1985). For the next 7,000 years drainage from the upper lakes bypassed Lake Erie. Isostatic uplift continued to raise the level water in the Lake Erie basin, but the cessation of over 90% of lake's former inflow probably created stagnant and perhaps eutrophic conditions. In fact, Lewis et al. (1999) concluded that the water level was sufficently low at this time for the lake to be within a closed basin.

Following the Lake Algonquin stage, the upper Great Lakes went through a series of successively lower stages until the North Bay-Ottawa River outlet was opened to the St. Lawrence embayment of the Atlantic Ocean. The lowest stages were Lake Chippewa (Lake Michigan basin) and Lake Stanley (Lake Huron basin). For at least 5,000 years the level in the Michigan-Huron basin was controlled by uplift of the Ottawa River outlet (Prest 1970). This period of gradually rising levels lasted until the Lake Nipissing stage (Lake Huron basin) when water was again transferred to the Lake Erie basin via the St. Clair - Detroit River system.

**Middle Lake Erie (8,000 to 3,000 YBP).** After 10,000 YBP the rising water in the Lake Erie basin slowed and at 8,000 YBP it leveled off at an elevation between 515 to 535 ft (157 to 163 m), followed by a very slow rise for the next 5,000 years. Hartley (1958) called this intermediate stage Middle Lake Erie. Forsyth (1973) explains the stable-level period as a response to decreased precipitation and increased evaporation during the Xerothermic or Hypsithermal Interval (Sears 1942, Phillips 1989) which counterbalanced the isostatic uplift. Near the close of this stage, about 3,000 YBP (Figure 2-9), drainage from the upper lakes returned to Lake Erie as a result of continued glacial uplift around North Bay, Ontario. This ended upper lakes drainage to the Lake Ontario basin and created the Lake Nipissing stages in the Lake Huron basin (Lewis 1969, Calkin and Feenstra 1985). This event (a major new influx of water from the upper lakes), plus more humid climatic conditions may have sharply increased water levels in Lake Erie and given impetus to the formation of a large delta in western Lake Erie at the mouth of the ancestral Detroit River (Herdendorf and Bailey 1989). Deposition of a massive delta in Lake St. Clair is also believed to have taken place at this time (5,000 to 3,500 YBP); radiocarbon dates for lacustrine clays (7,300 YBP) underlying the pre-modern St. Clair River delta show that formation of the delta began during Lake Nipissing time (Raphael and Jaworski 1982, Kaszycki 1985) and not during Lake Algonquin time (12,400 to 10,600 YBP) as ascribed by earlier investigators (Flint 1957, 1971). Coakley et al. (1999) also found evidence of a "Nipissing flood" in borehole data from Point Pelee.

**Modern Lake Erie (3,000 YBP to Present).** As Lake Erie rose to its approximate current level, 571 ft (174 m), shortly after 3,000 YBP, the south shore tributary channels which were deeply incised into lacustrine sediment and glacial till during the low water stage of Early Lake Erie, were flooded by lake encroachment, creating estuarine-type mouths (Herdendorf 1990). In Ohio alone, 16 $mi^2$ (42 $km^2$) of estuarine waters were formed at the mouths of 18 tributaries for a total linear distance of 100 mi (160 km) (Brant and Herdendorf 1972). As coastal erosion proceeded and beach-building sand was delivered to the littoral zone, massive sand spits were built at Point Pelee and Long Point in Ontario, at Presque Isle in Pennsylvania, at Woodtick Peninsula in Michigan, and at Cedar Point and Bay Point in Ohio. At the same time, barrier beaches and bars were formed across the mouths of most of the estuarine tributaries. Lake Erie waters appear to have now reached a near-stable level, although minor crustal warping appears to have

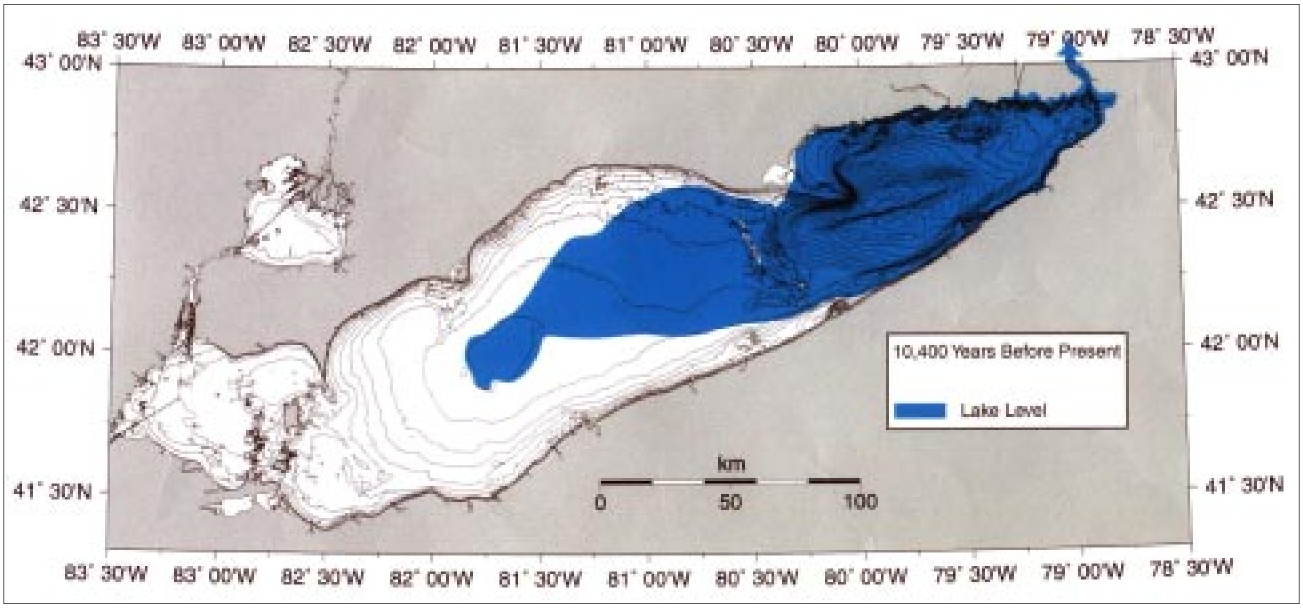


*Figure 2-8. Reconstruction of Early Lake Erie water level 10,400 years before the present; note that western Lake Erie is dry land (after Holcombe et al. 2003).*

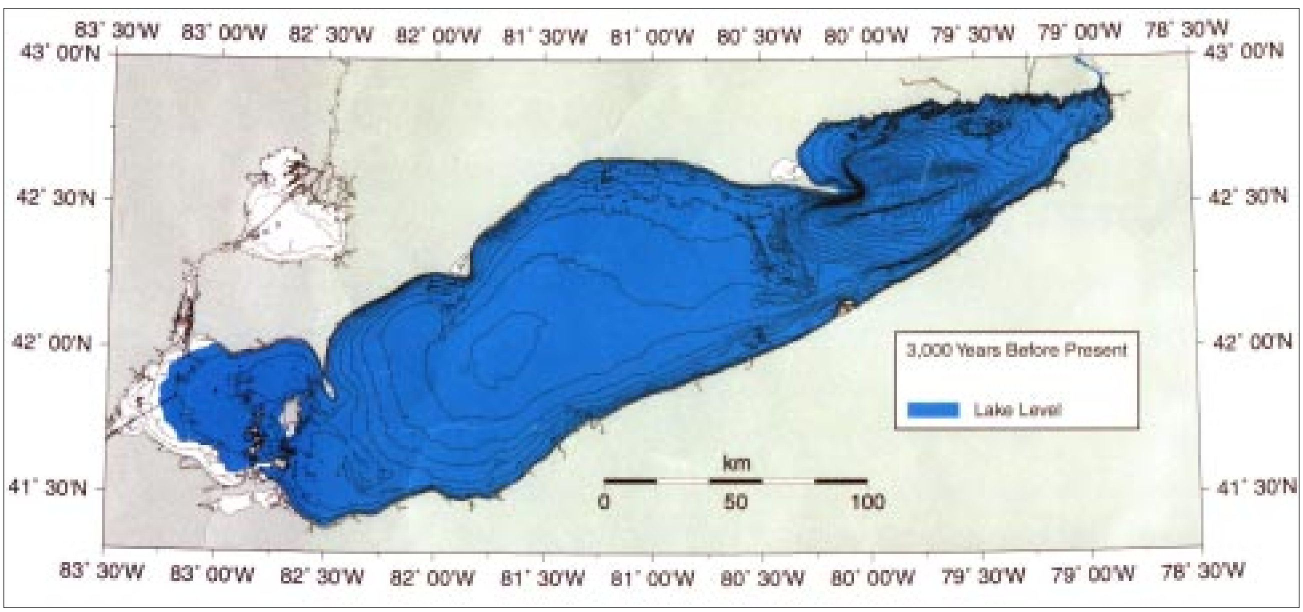


*Figure 2-9. Reconstruction of Lake Erie water level 3,000 years before the present; note that Kelleys Island is connected by a land bridge to the mainland (after Holcombe et al. 2003).*

continued to the present (Calkin and Feenstra 1985). A study by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data (1977) showed the maximum relative deformation rate for all measured sites in the Lake Erie basin is less than 2.5 in/century (64 mm/century) and concluded that present crustal movement rates for Lake Erie are minimal between the inlet and outlet of the lake; thus, there is currently little tectonic effect on mean lake level.

## Lake Erie Bottom Deposits

The lake bottom sediments surrounding or overlying the bedrock areas offshore of Kelleys Island were deposited in three modes: (1) by glaciers, (2) in prehistoric lakes (12,000 to 3,000 YBP), or (3) in modern Lake Erie (3,000 YBP to present). The continental ice sheets deposited a heterogeneous mixture of clay, silt, sand, and gravel known as glacial till. Geologically, the term "gravel" includes a wide range of particle sizes including granules, pebbles, cobbles, and boulders. The granitic and metamorphic rocks (erratics) found along the shore and on the lakefloor were derived from the Canadian Shield and transported southward by glaciers. These glaciers also cut the spectacular grooves at North Bay quarry in Kelleys Island State Park and numerous striations and shallow grooves along the island's eastern shore, which extend well offshore and appear much like a paved underwater highway. No such grooves or striations were noted at the project shore or offshore. Sediments deposited in the glacial and post glacial lake stages and in modern Lake Erie now cover much of the glacial till. Glacial lakes sediments (known as glaciolacustrine clays) lack the larger-sized components of till and are occasionally exposed as firm, blue-gray to reddish clay bottoms near the shoreline and fringes of the reefs.

The more recent deposits are less consolidated and consist mainly of sand, mud (semi-fluid silt and clay particles), and organic deposits such as peat. Surrounding Kelleys Island to a distance of a 3 mi (5 km) offshore, bedrock accounts for about 12% of the lake bottom; glacial till 2%; gravel 3%; sand 8%; sand and gravel mixture 10%; mud 20%; sand and mud mixture 45% (Herdendorf and Braidech 1972). The nearshore lake bottom surrounding much of Kelleys Island consists of three primary types: (1) glaciolacustrine clay with a veneer of recent muds or sand, (2) shelving bedrock, and (3) mixtures of sand, granules, pebbles, cobbles, and boulders (Table 2-2) over rock or clay. Only mixed cobbles and boulders appear to support abundant growths of submerged aquatic vegetation, especially in protected areas such as North Bay or around shallow shipwrecks. The clay/mud areas appear either too soft, erodible, or turbid while sand bottoms are too mobile and rock outcrops are too smooth to permit adequate attachment for these plants.

The bottom of North Bay is composed of a nearshore band of fine-grained sand 300-400 ft (90-120 m) wide at the State Park, which extends from the west side of the bay eastward to a small headland at Camp Patmos (Hartley and Verber 1960). Here the sand strip narrows and ends abruptly toward the northern end of the Predevelopment, Ltd. property. The sand is generally fine-grained, well-sorted, and formed into low bars paralleling the shore. Although the sand covers a fairly large area, it is relatively thin and rarely reaches 3 ft (1 m) in thickness. The troughs between the bars contain rounded pebbles and cobbles, which veneer glacial till. These materials generally comprise the bottom lakeward of the sand and near the shore where sand is absent. A fathogram analysis of the North Bay bottom in 1988 showed that about 6% of the bottom was covered with boulders greater than 10 in (25 cm) diameter (Herdendorf 1988). Much of the nearshore bedrock bottoms also contain a significant amount of rock rubble and various sizes of gravel.

The nearshore lake bottom off Long Point at the project location was investigated in conjunction with the submerged cultural resources survey in June 2004. Figure 2-6 depicts the bottom material from the shore to 300 ft (90 m) offshore. The influence of the embayment midway along the Predevelopment, Ltd. shore can be seen in the sandy deposits that have accumulated there (Table 2-3). Whereas, the influence of the rocky outcrops and rubble bottoms at the northern end of the property is relected in the headland that persists there. Table 2-4 contains descriptions of the bottom materials observed along nearshore transects. The sand on the nearshore bottom is primarily composed of medium- to fine-grained quartz particles, whereas the beach sand near the center of the embayment is dominated fragments of zebra mussel shells. To the southern end of the tract the beach material becomes coarser in size with patches of granules and pebbles at the waterline backed by limestone cobbles.

## Soils

The soils of the Predevelopment, Ltd. 6.45-acre (2.6-ha) tract consist of the Milton-Castalia-Millsdale association. This association occurs throughout the Long Point area of Kelleys Island (Redmond et al. 1971, Robbins et al. 2002) and is characterized by level (0 to 2% slope), well drained to poorly drained soils. The nearly flat ground surface of Long Point is underlain by shallow limestone bedrock, rubble, or channery (thin, flat slabs of limestone less than 10 in or 25 cm diameter). Fragmented bedrock lies at varying depths on the tract, up to approximately 3 ft (90 cm) below the soil surface. In the Building Envelope of the tract, no soil depths greater than 2.2 ft (67 cm) were encountered in test pits on a 10-m grid pattern (Figure 2-10 and Table 2-5).

Castalia (CcA), very channery silt loam soil (0-2% slope) occurs on about 80% of the Predevelopment,

## TABLE 2-2. UDDEN-WENTWORTH SEDIMENT GRAIN-SIZE CLASSIFICATION

| | *US Standard sieve mesh* | *Millimeters* | | *Phi (ϕ) units* | *Wentworth size class* |
|---|---|---|---|---|---|
| GRAVEL | *Use wire* | 4096 | | −12 | |
| | *squares* | 1024 | | −10 | boulder |
| | | 256 | 256 | − 8 | |
| | | 64 | 64 | − 6 | cobble |
| | | 16 | | − 4 | pebble |
| | 5 | 4 | 4 | − 2 | |
| | 6 | 3.36 | | − 1.75 | |
| | 7 | 2.83 | | − 1.5 | granule |
| | 8 | 2.38 | | − 1.25 | |
| | 10 | 2.00 | 2 | − 1.0 | |
| SAND | 12 | 1.68 | | − 0.75 | |
| | 14 | 1.41 | | − 0.5 | very coarse sand |
| | 16 | 1.19 | | − 0.25 | |
| | 18 | 1.00 | 1 | 0.0 | |
| | 20 | 0.84 | | 0.25 | |
| | 25 | 0.71 | | 0.5 | coarse sand |
| | 30 | 0.59 | | 0.75 | |
| | 35 | 0.50 | 1/2 | 1.0 | |
| | 40 | 0.42 | | 1.25 | |
| | 45 | 0.35 | | 1.5 | medium sand |
| | 50 | 0.30 | | 1.75 | |
| | 60 | 0.25 | 1/4 | 2.0 | |
| | 70 | 0.210 | | 2.25 | |
| | 80 | 0.177 | | 2.5 | fine sand |
| | 100 | 0.149 | | 2.75 | |
| | 120 | 0.125 | 1/8 | 3.0 | |
| | 140 | 0.105 | | 3.25 | |
| | 170 | 0.088 | | 3.5 | very fine sand |
| | 200 | 0.074 | | 3.75 | |
| | 230 | 0.0625 | 1/16 | 4.0 | |
| SILT | 270 | 0.053 | | 4.25 | |
| | 325 | 0.044 | | 4.5 | coarse silt |
| | | 0.037 | | 4.75 | |
| | | 0.031 | 1/32 | 5.0 | |
| | | 0.0156 | 1/64 | 6.0 | medium silt |
| | *Use* | 0.0078 | 1/128 | 7.0 | fine silt |
| | *pipette* | 0.0039 | 1/256 | 8.0 | very fine silt |
| CLAY | *or* | 0.0020 | | 9.0 | |
| | *hydro-* | 0.00098 | | 10.0 | clay |
| | *meter* | 0.00049 | | 11.0 | |
| | | 0.00024 | | 12.0 | |
| | | 0.00012 | | 13.0 | |
| | | 0.00006 | | 14.0 | |

**TABLE 2-3. PHYSICAL DESCRIPTION OF THE LAKE ERIE SHORELINE ALONG PREDEVELOPMENT, LTD. PROPERTY, LONG POINT, KELLEYS ISLAND, OHIO**

| Transect Line | Abandoned Road $C_L$ | Crest Cobble Storm Berm | Boulder & Cobble Beach | Bedrock Ledge | Cobbles & Pebbles Beach | Bedrock Ledge | Sand Beach | Water-line |
|---|---|---|---|---|---|---|---|---|
| A | -16.0 | 0.0[1] | 5.0 | 7.0 | 11.0[2] | | 30.0 | 34.0 |
| B | | 0.0 | | 5.0 | 9.0[3] | 28.0 | | 39.0 |
| C | | 0.0 | 5.0 | 13.0 | 16.0 | 22.0 | | 37.0 |
| D | -14.0 | 0.0 | | 5.0 | 19.0[4] | 38.0 | | 38.0 |
| E | | 0.0 | 5.0 | 12.0 | | | | 33.0 |
| F | -19.0 | 0.0[5] | 7.0 | 17.0[6] | | | | 32.0 |
| G | | 0.0 | 6.0[7] | | 16.0[8] | 26.0 | | 35.0 |
| H | -17.0 | 0.0 | | 5.0[9] | | | | 30.0 |
| I | | 0.0 | 8.0[10] | 15.0 | | | | 36.0 |
| J | | 0.0 | 5.0 | 25.0 | | | | 41.0 |
| K | | 0.0 | | | 24.0[11] | 35.0 | | 40.0 |
| L | -9.0 | 0.0 | 4.0[12] | | | | 14.0 | 39.0 |
| M | | 0.0 | 5.0 | | | 28.0 | | 28.0 |
| N | | 0.0 | 5.0 | 13.0 | | | | 23.0 |
| O | -14.0 | 0.0[13] | 5.0 | 17.0 | | | | 25.0 |
| P | | 0.0 | | 5.0 | 18.0 | 22.0 | | 27.0 |
| Q | | 0.0 | 5.0 | | | | | 28.0 |
| R | | 0.0 | 5.0 | | 17.0 | 27.0 | | 34.0 |
| S | | 0.0 | 5.0 | 14.0[14] | 25.0 | | | 32.0 |

Notes:
1. Backside of storm berm begins at -7.0 ft.
2. Thin layer of cobbles and pebbles over bedrock.
3. Beach composed primarily of pebbles from 21 to 28 ft.
4. Large boulders (bedrock slabs) near shoreline.
5. Backside of storm berm begins at -7.0 ft.
6. Vertical bedrock ledge at shore, 1.5 ft above waterline.
7. Beach composed primarily of zebra mussel shells and limestone cobbles.
8. Beach composed primarily of boulder slabs and zebra mussel shells.
9. Large slabs of broken bedrock and granite boulder (5 ft diameter).
10. Beach composed primarily of small cobbles and pebbles.
11. Beach composed primarily of sand and zebra mussel shells.
12. Upper part of beach primarily sand grading to boulders..
13. Backside of storm berm begins at -6.0 ft.
14. Bedrock in 7 “stair-step” layers.

Distances in feet from crest of the cobble storm berm, perpendicular to the shoreline toward Lake Erie. Measurements made on June 8, 2004 from 9:00 am to 6:00 pm; water level 571.9 IGLD 1985.

**TABLE 2-4. PHYSICAL DESCRIPTION OF THE LAKE ERIE BOTTOM ADJACENT TO PREDEVELOPMENT, LTD. PROPERTY, LONG POINT, KELLEYS ISLAND, OHIO**

| Transect Line | Waterline Material | Waterline (elevation) | Bedrock (elevation) | Boulders & Cobbles (elevation) | Sand (elevation) |
|---|---|---|---|---|---|
| A | Sand over bedrock | 34.0 (+2.7) | 34.0 (+2.7) | 49.0 (+1.3) | 125.2 (-2.9) |
| B | Bedrock ledge | 39.0 (+2.7) | 39.0 (+2.7) | 63.0 (+1.1) | 106.0 (-1.9) |
| C | Bedrock ledge | 37.0 (+2.7) | 37.0 (+2.7) | 60.6 (+0.5) | 112.0 (-3.3) |
| D | Bedrock ledge | 38.0 (+2.7) | 38.0 (+2.7) | 56.2 (+0.5) | 111.5 (-2.0) |
| E | Bedrock ledge | 33.0 (+2.7) | 33.0 (+2.7) | 42.7 (+1.2) | 89.6 (-2.0) |
| F | Bedrock ledge | 32.0 (+2.7) | 32.0 (+2.7) | 60.3 (+0.2) | 91.6 (-1.9) |
| G | Bedrock ledge | 35.0 (+2.7) | 35.0 (+2.7) | 53.1 (+0.7) | 105.5 (-1.5) |
| H | Bedrock ledge | 30.0 (+2.7) | 30.0 (+2.7) | 66.0 (-0.3) | 97.5 (-1.4) |
| I | Bedrock ledge | 36.0 (+2.7) | 36.0 (+2.7) | 76.0 (-0.3) | 111.0 (-1.3) |
| J | Bedrock ledge | 41.0 (+2.7) | 41.0 (+2.7) | 91.0 (-1.1) | 141.0 (-1.8) |
| K | Bedrock ledge | 40.0 (+2.7) | 40.0 (+2.7) | 190.0 (-2.3) | 240.0 (-3.3) |
| L | Sand beach | 39.0 (+2.7) | 41.0 (+2.2) | [all bedrock with scattered boulders] | |
| M | Bedrock ledge | 28.0 (+2.7) | 28.0 (+2.7) | [all bedrock, smooth surface] | |
| N | Bedrock ledge | 23.0 (+2.7) | 23.0 (+2.7) | [all bedrock with scattered boulders] | |
| O | Bedrock ledge | 25.0 (+2.7) | 25.0 (+2.7) | [all bedrock with scattered boulders] | |
| P | Bedrock ledge | 27.0 (+2.7) | 27.0 (+2.7) | [all bedrock with cobble patches] | |
| Q | Boulder & cobble beach | 28.0 (+2.7) | 28.0 (+2.7) | [all cobbles] | |
| R | Bedrock ledge | 34.0 (+2.7) | 34.0 (+2.7) | 87.4 (-1.8) | [all cobbles] |
| S | Cobble & pebble beach | 32.0 (+2.7) | | 32.0 (+2.7) | [all cobbles] |

Notes:
Distances in feet from crest of the cobble storm berm, perpendicular to the shoreline, toward Lake Erie.
Elevation in feet above (+) or below (-) Low Water Datum (LWD) for Lake Erie 569.2, IGLD 1985.
Measurements made on June 8, 2004 from 9:00 am to 6:00 pm; water level 571.9 ft, equivalent to 2.7 ft above LWD.

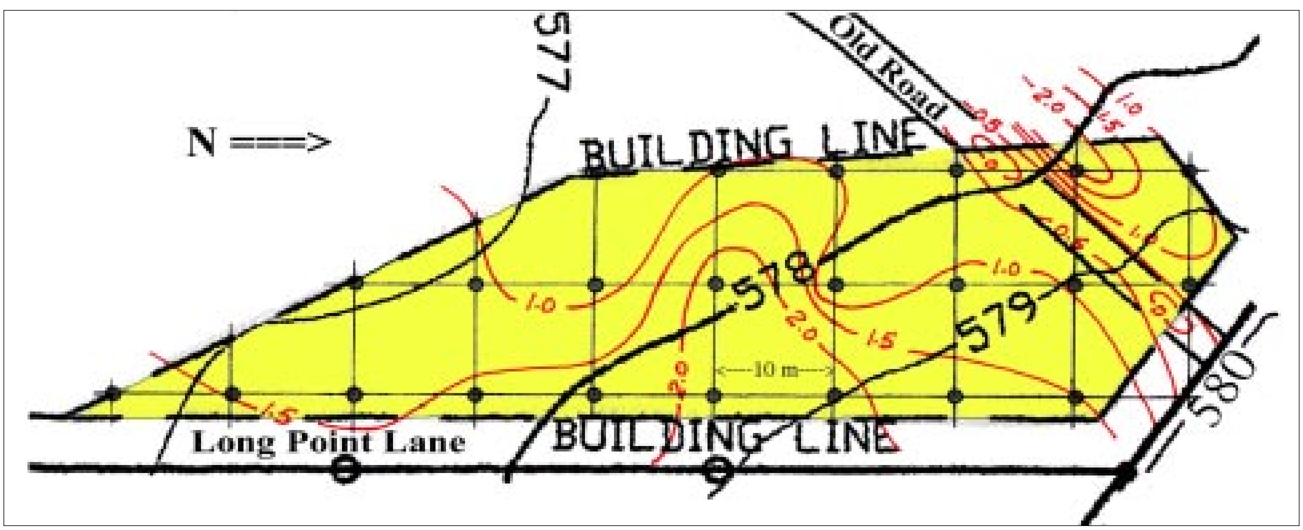


*Figure 2-10. Map of the Building Envelope, showing contours of depth to bedrock as determined from shovel test pits and soil cores.*

**TABLE 2-5. PHYSICAL CHARACTERISTICS FOR SHOVEL TEST PITS, PREDEVELOPMENT, LTD. PROPERTY, BUILDING ENVELOPE LONG POINT, KELLEYS ISLAND, OHIO**

| Location | Soil Type | A Horizon Thickness (ft) | B/C Horizon Thickness (ft) | Depth to Bedrock (ft) | Artifacts (no.) |
|---|---|---|---|---|---|
| A-1 | MnA | 0.9 | 0.7 | 1.6 | Chert material (8) |
| B-1 | MnA | 0.9 | 0.6 | 1.5 | Chert material (7) |
| C-1 | MnA | 0.9 | 0.5 | 1.4 | Chert material (9) |
| D-1 | MnA | 0.8 | 0.7 | 1.5 | Chert material (15) |
| E-1 | MnA | 0.7 | 0.9 | 1.6 | Chert material (8) |
| F-1 | MnA | 0.9 | 1.3 | 2.2 | Chert material (10) |
| G-1 | MnA | 0.9 | 1.3 | 2.2 | Chert material (16) |
| H-1 | MnA | 0.9 | 0.7 | 1.6 | Chert material (10) |
| I-1 | MnA | 0.8 | 0.7 | 1.5 | Chert material (5) |
| | | | | | |
| C-2 | MnA | 0.7 | 0.4 | 1.1 | Chert material (17) |
| D-2 | CcA | 1.0 | 0.0 | 1.0 | Chert material (10) |
| E-2 | CcA | 0.8 | 0.0 | 0.8 | Chert material (4) |
| F-2 | MnA | 0.9 | 1.2 | 2.1 | Chert material (7) |
| G-2 | CcA | 0.8 | 0.0 | 0.8 | Chert material (6) |
| H-2 | CcA(?) | 1.1 | 0.0 | 1.1 | Chert material (5) |
| I-2 | CcA | 1.0 | 0.0 | 1.1 | Chert material (5) |
| J-2 | CcA | 0.9 | 0.0 | 0.9 | Chert material (5) |
| | | | | | |
| E-3 | CcA | 0.9 | 0.0 | 0.9 | Chert material (1) |
| F-3 | CcA | 1.0 | 0.0 | 1.0 | None |
| G-3 | CcA | 1.0 | 0.0 | 1.0 | Chert material (5) |
| H-3 | CcA | 0.7 | 0.0 | 0.7 | None |
| I-3 | MnA | 0.9 | 1.3 | 2.2 | Chert material (10) & Glass fragments (2) |
| J-3 | CcA | 1.0 | 0.0 | 1.0 | Chert material (5) & Glass fragments (4) |

Soil Type Legend:

CcA — Castalia very channery silt loam, 0 to 2% slope
MnA — Milton silt loam, 0 to 2 % slope

Note:

Depth to bedrock indicates refusal of coring device at bedrock surface or in channery stones.

Ltd. tract (Figure 2-11). Channery, fragments of limestone 2 to 10 in (5 to 25 cm) diameter occur in the Castalia soil and may make up to 50% or more of the material in the upper soil horizons. The rubble can extend to depths of nearly 3 ft (90 cm); below this depth, solid limestone bedrock exists. The degree to which interstitial spaces between the rubble is filled with soil decreases with depth. The term loam refers to a soil with relatively equal amounts of clay, silt, and sand, making it permeable to water circulation. This soil is well drained with rapid permeability.

Milton (MnA) silt loam soil (0-2% slope), formerly mapped (Redmond et al. 1971) as Lewisburg silt loam, moderately shallow variant (LgA), is also present on about 10% of the Predevelopment, Ltd. tract, comprising the southeasterly portion of the Building Envelope and a small area immediately to the south of the envelope (Figure 2-11). Milton subsoils are a clay loam that may contain small gravel to larger limestone fragments; solid bedrock typically occurs at depths of 20 to 36 in (50 to 90 cm). This soil is well drained with moderate to moderately slow permeability.

Millsdale (MmA) silty clay loam soil (0-2% slope) forms the other 10% of the tract's soil and is present to the south of the Building Envelope and mainly to the east of the access road (Figure 2-11). This soil is very poorly drained in comparison to the other soils on the tract and occupies the lowest interior elevations. Vernal pools occur in shallow depressions on this hydric soil, which support sedges such as *Carex frankii.* Millsdale soil becomes cloddy if worked when too wet and requires drainage to raise field crops. Most undrained areas are in permanent pasture.

Soil information depicted on the soil survey map of Long Point (Figure 2-11), was confirmed within the Building Envelope, by test holes dug under the supervision of the Erie County General Health District on September 11, 2002 and further verified at 23 test pits (10-m grid) during the Phase I Cultural Resources Study conducted by EcoSphere Associates on May 27, 2004. All of the soils on the tract have severe limitations for septic tank absorption fields due to shallowness of the bedrock and in the case of the Millsdale soil, due to the high water table. Castalia soil is not considered as prime farmland, but Milton and Millsdale are listed as prime farmland with a relative cropland productivity (RCP) rating of 73 and 82, respectively (Martin and Prebonick 1994:35). The RCP is an index number based on the most productive soils in Erie County having a rating of 100. For example the best soil (Colwood loam) has a corn yield of 165 bushels per acre; thus Milton soil would be expected to produce 120 bushels and Millsdale soil, 135 bushels.

## Climate

### Climatic Trends

During the Pleistocene epoch, 1.6 million to 10,000 years before the present (YBP), at least four major glaciers advanced over the Great Lakes. Ice more than 2 km thick slowly proceeded across the landscape, scouring the surface, filling valleys, and leveling hills. The last glacier (Wisconsinan) reached as far south as Cincinnati (18,000 YBP) before it began to recede (Forsyth 1961). The air temperatures ahead of the glacier were probably 10°C cooler than at present—spruce forests extended into Florida and Texas (Terasmae 1961). As the glacier receded to the northeast, reaching present-day Niagara Falls about 12,500 YBP, a relatively dry tundra climate dominated northern Ohio in its wake (Beltzner 1976). As the temperature slowly warmed and moisture increased, conifer forests became more prevalent as shown in cores where spruce pollen exceeded 50% (Shane 1994).

By 10,000 YBP the ice sheet had retreated north of the modern Great Lakes and air temperatures in northern Ohio and southern Ontario had risen to only 3 to 4°C lower than at present (Phillips 1989). Gradually at first, then more rapidly, spruce and other conifers were replaced by oak and other deciduous trees. The first evidence of human occupation in the region is from this period as nomadic Paleo-Indians hunted in tributary valleys to Lake Erie (Shane 1981). The lake's water level was about 65 to 80 ft (20 to 25 m) lower than present leaving the western basin dry and the central and eastern basins partially dry (Herdendorf and Bailey 1989, Holcombe et al. 2003).

The climate continued to warm after 10,000 YBP with air temperatures in the Great Lakes region taking a dramatic jump of 4 to 5°C within a millennium. Pollen studies show that spruce was entirely replaced by hardwood trees (Cushing 1965, Shane 1994), as boreal forests and tundra gave way to deciduous woodlands and prairie grasslands. A warmer climate also favored a more diverse fauna, including the propagation of game animals along the valleys of streams flowing into Lake Erie. Here, Early Archaic

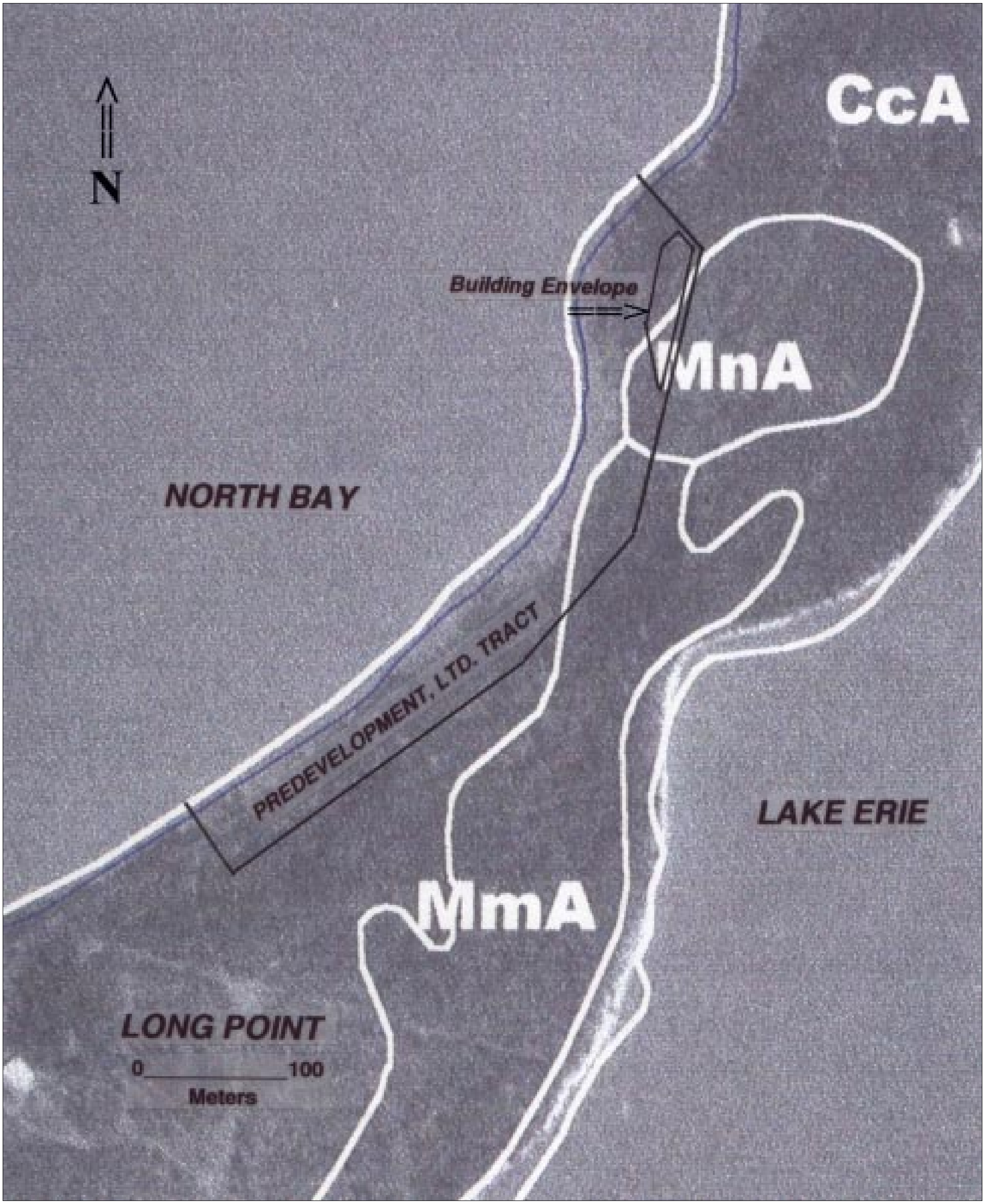


*Figure 2-11. Soils map of the Predevelopment, Ltd. tract on Long Point of Kelleys Island (after Robbins et al. 2002).*

Indians established hunting camps on the bluffs of the lake and its tributaries around 8,000 YBP (Shane 1992, Abel 1994).

As the ice moved farther north, the prevailing winds shifted from off the ice front to more westerly, as dryer and warmer weather spread across the region (Webb and Bryson 1972). Between 8,000 to 6,000 YBP the region was quite mild, perhaps 2 to 3°C warmer than at present, initiating a phase known as the Climatic Optimum or Hypsithermal Interval (Phillips 1989). Pollen records indicate that subtropical plants grew as far north as Minnesota during this interval (Ross 1995). Following the onset of the warmer phase, conditions became somewhat dryer and drought-resistant (prairie) vegetation moved into the region from the southwest.

Starting about 5,500 YBP there was another rapid change in climate as the mean temperature dropped nearly 5°C in 1,500 years. This cooler period, known as Neoglaciation (Flint 1971), was accompanied by the growth of polar glaciers and a return of conifer trees to northern Ohio (Reeder and Eisner 1994). Historical evidence points to a cool, but warming period from about 3,000 to 1,500 YBP. Woodland Indian cultures flourished during this period, establishing agrarian villages on promontories in northern Ohio, including bluffs overlooking tributaries to the lake (Shane 1981). By this time Lake Erie had risen to a level that flooded the valleys of most tributaries forming estuaries and deltaic islands, as shown by pollen records for aquatic and wetland plants (Reeder and Eisner 1994).

Beginning around 1,200 YBP, a 500-year mild phase (Medieval Period, AD 800 to 1,300) ensued with temperatures 1°C warmer than present (Phillips 1989). The Whittlesey (Erie) Indians inhabited northern Ohio during the mild phase, constructing small, fortified villages on high banks of streams that empty into Lake Erie (Brose 1976, Otto 1980). Swain (1984) speculated that near the end of this mild climate interval, the first European settlement in the region could have taken place when a Norse expedition may have traversed the length of the Great Lakes (ca. 1362), leaving an inscription on the controversial Kensington Runestone in northeastern Minnesota.

In the later part of the 14th century (700 YBP), the climate swung back toward progressively colder, wetter conditions. Another Neoglaciation episode occurred from AD 1430 to 1850 that is sometimes called the “Little Ice Age” (Ross 1995). At this time the glaciers in northern Canada made a modest advance as northern Ohio and southern Ontario became considerably colder. Presumably in response to adverse climatic conditions and hostilities among Indian groups, most of Ohio and western Pennsylvania were without inhabitants from the 15th to 18th centuries, except for small settlements of Whittlesey Indians along the Lake Erie shore and Fort Ancient Indian villages in the Ohio River valley, where these water bodies moderated the climate (Otto 1980).

Settlement of the Great Lakes region by Europeans began appreciably by the middle of the 18th century. Summers were still cool during the first half of the 19th century. In particular, 1816 has been called the “year without a summer” because frosts occurred each month—volcanic ash from the eruption of Mount Tambora on the island of Sumbawa in Indonesia appears to be associated with this climatic event (Phillips 1989). Following this cold episode temperatures warmed somewhat and then cooled again in the mid 20th century. In recent years there has been another warming trend which may be, in part, related to the “greenhouse effect”—the warming of the Earth’s atmosphere because of its transparency to incoming sunlight and opacity to heat radiated from Earth (opacity, hence heat, is increased by added amounts of carbon dioxide, water vapor, methane, and dust in the atmosphere).

## Modern Climate

The climate of northcentral Ohio is classified as “temperate—humid continental—long summer,” signifying a middle latitude location (N35°– 45°) in the interior of a large land mass well removed from oceanic influences with ample rainfall, warm to hot summers, and cold winters. These climatic characteristics are expressed in four distinct seasons, large seasonal temperature ranges, frequent precipitation, and sudden changeability with the rapid passage of different weather systems through the area. While the prevailing winds are from the southwest, one or two weather disturbances affect Kelleys Island each week, bringing changes in wind direction, overcast skies, and often precipitation. The settled weather associated with high-pressure systems is thus interrupted every few days by disturbances such as fronts or low-pressure areas which can bring warm subtropical air from the south or cold Arctic air from the north (Schmidlin 1996).

Thus, the climate of Kelleys Island is marked by large fluctuations in temperature and precipitation. Because of the proximity of the lake, winds from the northerly quadrants tend to lower daily temperatures in the summer, while raising them in the winter when the lake is open. The growing season on the island averages 205 days (frostless days). Summers are moderately warm and humid with about 16 days where the temperature exceeds 32°C (90°F). Winters are generally cold and cloudy, however, the tempering effect of the lake limits subzero (F°) temperatures to only 3 out of 5 years on the average. As is typical for continental climates, precipitation is highly variable on a yearly basis, but in the watershed it is generally abundant and evenly distributed with autumn being the driest season. Average annual precipitation is approximately 31.7 in (80.5 cm). Winds average 7 knots (10 km/hr) in the summer and 10 knots (14 km/hr) in the winter. Although the prevailing winds are southwesterly, Erie County has a history of severe storms from the northeast and northwest that have caused extensive damage to the mainland shoreline (Carter and Guy 1980). Average monthly weather conditions for Erie County are tabulated in Table 2-6 and monthly average precipitation and maximum/minimum average daily air temperatures for Sandusky, Ohio (9 mi or 14.5 km south of Kelleys Island) are given in Table 2-7.

## Lake Effect

Lake Erie has a modifying effect on the weather at Kelleys Island. Winds off the lake tend to lower the air temperatures on summer days and raise them on winter days. The daily variation in air temperature becomes greater with increasing distance from the lake and the average annual precipitation increases slightly. The frost-free period for communities in the south of the island are given below:

| Growing Season | Days |
|---|---|
| Kelleys Island | 205 |
| Sandusky (on Lake Erie mainland shore) | 194 |
| Berlin Heights (6 km south of Lake Erie) | 168 |
| Norwalk (17 km south of Lake Erie) | 154 |

Because water has a higher specific heat (capacity to absorb thermal energy in relation to temperature change) than soil, Lake Erie changes temperature more slowly than the surface of the land, delaying the change of seasons along the shore. Lake Erie absorbs a great amount of heat in the spring and summer with a relatively small change in temperature and slowly releases that heat in the fall and winter. The heat capacity of water not only permits the lake to act as a buffer against wide fluctuations in the coastal environment, it narrows the range of temperatures to which an aquatic organism is subjected as compared to those organisms living on land. Lake temperatures rarely exceed 27°C, whereas air temperatures as high as 42°C have been recorded on the adjacent mainland (Bolsenga and Herdendorf 1993).

As the water gradually warms in the spring, the island remains cooler than the more southerly portions of mainland. After reaching a temperature of 24-27°C in August, the lake begins to cool slowly during autumn and early winter, tempering the first cold waves of winter and pushing back the first freeze by several weeks. Lake Erie also adds moisture to the air during the cooling period. Evaporation of lake water is greatest as this time because the water is much warmer than the air. The added moisture results in frequent cloudiness; sunny days usually occur less than 20% of the time in November (Herdendorf et al. 1986). These climatic factors favored the development of viticulture and the wine making industry that flourished on Kelleys Island from the 1840s until Prohibition (1920-1933) dealt it a near fatal blow (Morrison 1950:112).

Lake Erie is large enough to induce lake-land breezes. During the day in summer, the lake is typically cooler than the surrounding shore, and a breeze blows onshore to replace rising air masses over the warmer land. The effect of these cooling breezes can extend 30 km inland (Burns 1985). At night the lake temperature remains about constant while the land quickly cools, and the direction of the breeze changes and blows off the land to replace air masses rising over the lake. These effects cause downdrafts of air over the lake during the day which tend to disperse clouds in front of a shoreward moving lake breeze front, resulting in clear skies over the lake and island for 30-50% of the days in summer (Eichenlaub 1979). Conversely, at night updrafts over the lake can lead to severe thunderstorms (Phillips and McCullochh 1972).

## Wind

Southwesterly winds prevail in all months of the year, a feature common to temperate regions of the northern hemisphere. In fall and winter, northwesterly winds can also occur frequently, reaching velocities

**TABLE 2-6. AVERAGE WEATHER CONDITIONS FOR ERIE COUNTY, OHIO**

| DAYS | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sunny | 10 | 10 | 12 | 14 | 17 | 18 | 21 | 20 | 18 | 17 | 10 | 9 |
| Rainy | 5 | 5 | 6 | 7 | 7 | 6 | 5 | 5 | 5 | 5 | 4 | 5 |
| Thunderstorm | 0 | 0 | 1 | 2 | 5 | 7 | 7 | 5 | 3 | 1 | 0 | 0 |
| Snowy (> 2.5 cm) | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| Hot (> 32°C) | 0 | 0 | 0 | 0 | 5 | 6 | 5 | 3 | 0 | 0 | 0 | 0 |
| Cold (< 0°C) | 27 | 23 | 20 | - | 0 | 0 | 0 | 0 | 0 | - | 13 | 23 |
| WIND | | | | | | | | | | | | |
| Speed (km/hr) | 15 | 15 | 18 | 15 | 13 | 11 | 11 | 9 | 11 | 13 | 15 | 15 |
| Direction (dominant) | SW | SW | SW | SW | SW | SW | SW | SW | SW | SW | SW | SW |
| Gusts (days) | 4 | 4 | 5 | 5 | 3 | 3 | 2 | 1 | 2 | 3 | 4 | 5 |
| LAKE | | | | | | | | | | | | |
| Temperature (°C) | < 1 | < 1 | 2 | 6 | 13 | 19 | 22 | 24 | 21 | 14 | 7 | 2 |
| Ice thickness (cm) | 20 | 30 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| SUNSHINE | | | | | | | | | | | | |
| Percent (% possible) | 32 | 38 | 44 | 51 | 60 | 68 | 70 | 65 | 63 | 58 | 39 | 34 |
| Clouds (% sky) | 80 | 80 | 70 | 70 | 60 | 60 | 50 | 50 | 60 | 60 | 80 | 80 |
| AIR TEMPERATURE | | | | | | | | | | | | |
| > Probability (%) | | | | | | | | | | | | |
| -5°C | 82 | 86 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 96 |
| 0°C | 26 | 26 | 93 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 53 |
| 5°C | 0 | 0 | 15 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 69 | 0 |
| 10°C | 0 | 0 | 0 | 44 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 0 |
| 15°C | 0 | 0 | 0 | 0 | 59 | 100 | 100 | 100 | 100 | 15 | 0 | 0 |
| 20°C | 0 | 0 | 0 | 0 | 0 | 89 | 100 | 100 | 26 | 0 | 0 | 0 |
| 25°C | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 11 | 0 | 0 | 0 | 0 |

> = greater than
< = less than

Data Sources:
Redmond et al. (1971), Herdendorf et al. (1986), Herdendorf (1987), Bolsenga and Herdendorf (1993).

of 40 to 50 mi/hr (65 to 80 km/hr) during severe storms (Herdendorf 1987). In spring, winds from the northeast are common, with storms producing velocities of 30 to 40 mi/hr (50 to 65 km/hr). Recent wind observations at a research station on Old Woman Creek (Erie County, Ohio) demonstrate the seasonal differences in wind patterns (Figure 2-12). Wind blowing over land generally has a lower velocity than wind blowing over open Lake Erie. This difference is caused by greater frictional drag over land. This difference is greatest in the cooler months when the temperature differential between air and water is greatest. Richards and Phillips (1970) found that on average the air to lake ratio was 1:1.66 (i.e. a 10 km/hr wind over land would have a velocity of 16.6 km/hr over the lake). Thunderstorms typically occur over the island about 30 days each year. Tornadoes are rare, but water spouts are occasionally reported.

**TABLE 2-7. WEATHER DATA FOR SANDUSKY, OHIO**

AVERAGE DAILY

| | AIR TEMPERATURE (°C) Minimum | Maximum | | PRECIPITATION (cm) Average | Snowfall |
|---|---|---|---|---|---|
| January | -6.1 | 1.1 | | 6.1 | 18.3 |
| February | -5.6 | 2.2 | | 5.6 | 16.0 |
| March | -1.1 | 7.2 | | 7.3 | 14.4 |
| April | 4.4 | 13.9 | | 8.2 | 2.8 |
| May | 10.6 | 21.1 | | 8.7 | 0.0 |
| June | 16.1 | 26.1 | | 10.4 | 0.0 |
| July | 18.3 | 28.3 | | 9.2 | 0.0 |
| August | 17.8 | 27.8 | | 8.2 | 0.0 |
| September | 13.9 | 23.9 | | 7.1 | 0.0 |
| October | 8.3 | 18.3 | | 5.1 | 0.0 |
| November | 1.7 | 10.0 | | 5.6 | 6.4 |
| December | -3.9 | 3.3 | | 5.2 | 15.5 |
| YEAR MEAN | 6.2 | 15.3 | TOTAL | 86.7 | 73.7 |

Data Source:
U.S. Weather Service; Sandusky, Ohio (Period of Record: 1936-1965).

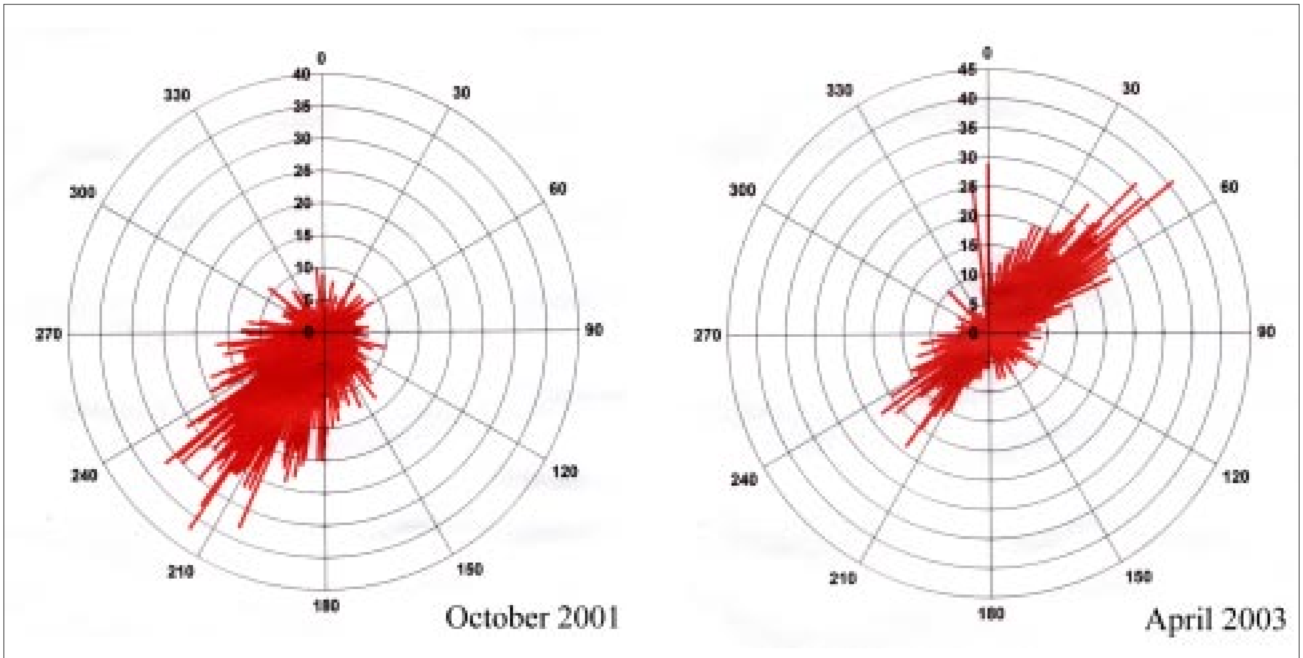


*Figure 2-12. Monthly wind roses generated from measurements at Old Woman Creek National Estuarine Research Reserve (Huron, Ohio), showing dominant southwest wind patterns in the fall and the influence of northeast storms in the spring, velocities in km/hr (Herdendorf et al. 2004).*

### Solar Radiation

Kelleys Island experiences a maximum of approximately 15 hours of daylight in the summer and a minimum of 9 hours in the winter. Because of the cloud-producing effect of the lake, December and January ordinarily have less than 40% of possible sunshine, while June and July average more than 70%. The mean daily solar radiation received at the surface of Lake Erie in June is about 5500 kcal/$m^2$ versus only 900 kcal/$m^2$ in December (Herdendorf 1987).

### Ice Cover

The shallow depth of Lake Erie and its small thermal reserve as compared to the other Great Lakes results in a rapid response to changing atmospheric conditions. Ice cover extends over 90% of Lake Erie's surface most winters (Assel et al. 1983). Ice cover usually develops in the western end of the lake in the last half of December. During early March western Lake Erie usually has 40% to 60% ice coverage and by the end of the month this basin is largely open water. This period can vary considerably, depending on the severity of the winter. In the latter part of the 19th and early in the 20th century ice was cut in North Bay for the large ice house serving the island's nearly 2,000 population. Ice in the bay was up to 2 ft (0.6 m) thick according to residents of this island who worked for the ice company (Hartley and Verber 1960:23). There were no reports of ice ever piling up to form windrows on the north shore, in their memories, with the exception of the tip of Long Point on the eastern edge of North Bay (Figure 2-13). In February 1956, ice piled up 7 ft (2 m) high or more at a rock ledge approximately 1,000 ft (300 m) north of the shore at the 4-H Camp. Winds up to 52 mi/hr (84 km/hr) from the west occurred on February 25, 1956, the date of the pile-up (Hartley and Verber 1960). Residents of the island also reported that a crack usually forms on a line from the North Bay dock at the State Park to Long Point separating the ice in the bay from the main ice pack in the lake. Ice pile-ups would normally occur along such an edge, but they apparently do not form here because of the short wind fetch. Also, numerous reefs and islands form a natural barrier for on shore winds and the bay is land-locked on the west, south, and east. Some small ice pile-ups have also been reported in the vicinity of the steambarge *ADVENTURE* shipwreck, off the southern end of the Predevelopment, Ltd. property (Russell Matso, personal communication, 2001).

## Water Quality and Levels

Lake Erie has undergone major changes in its chemistry and biology over the last 25 years. Nutrient inputs into the lake, particularly from point sources, have diminished (Fuller et al. 1995) and invasions by exotic species, particularly the zebra mussel *Dreissina polymorpha*, have changed the ecology of Lake Erie dramatically.

### Lake Erie Visibility

A Secchi disc is an easy, but reliable way to gauge water clarity. Employed since 1865, this simple 8-in (20-cm) metal disc painted in black and white quarters is lowered into the water until the observer can no longer distinguish its outline. The length of line from the water surface to the disc is then measured to determine the water's transparency. The past decade has seen a remarkable improvement in the clarity of Lake Erie waters. At Kelleys Island, typical underwater visibility was under 3 ft (1 m) during the 1960s-1980s, largely due to turbidity caused by dense populations of floating algae and suspended sediment particles. Currently, it is not unusual to observe submerged objects at a distance of 10 to 20 ft (3 to 6 m) or more. This change was brought about by years of efforts to reduce phosphorus pollution and by the collective filtering of billions of zebra mussels that have recently colonized the lake's bottom. As the waters have become clearer, recreational divers have taken to the lake in greater and greater numbers. Underwater exploration has become a popular sport, particularly with the lure of the up to 40 shipwrecks reported in the waters surrounding the Lake Erie islands, many of them yet to be discovered and documented.

### Water Levels

The long-term (1918 to 1996) mean, maximum, and minimum monthly water levels for Lake Erie are given in Table 2-8. These data show that the elevation of Lake Erie has a range of 1.6 m from the lowest levels recorded in the mid-1930s to the highest levels recorded in the mid-1980s. On a month-to-month basis, the lake tends to be lowest in winter and highest in late spring or early summer. The water budget for Lake Erie is composed of a number of factors which contribute to either inflow, outflow, or change in the amount of water stored in the lake:

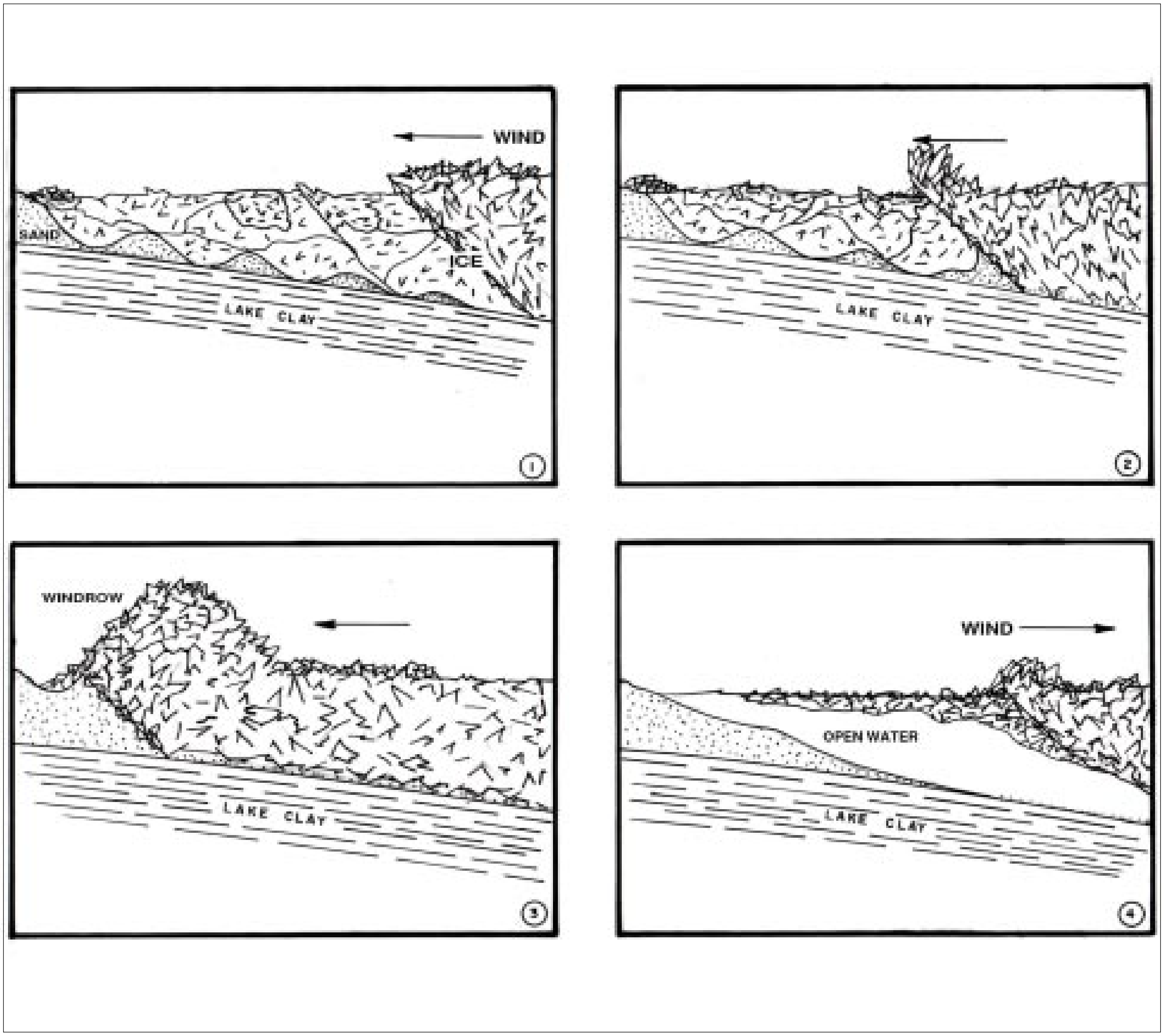


*Figure 2-13. Sequence of events as ice moves onshore and offshore creating a windrow and modifying the lake bottom (after Liebenthal and Herdendorf 1966).*

| Inflow Factors | |
|---|---|
| inflow from the Detroit River | (80%) |
| precipitation falling on the lake surface | (11%) |
| runoff from rivers in the lake basin | (9%) |

| Outflow Factors | |
|---|---|
| outflow through Niagara River | (88%) |
| evaporation from the lake surface | (8%) |
| outflow via Welland Canal diversion | (3%) |
| consumptive use of water from lake | (1%) |

The difference between the inflow and the outflow is the change in storage, which in turn changes lake levels. Because of high spring runoff and low evaporation, storage of water in Lake Erie is highest in the spring. Levels are lowest in the fall and winter due to high evaporation and low runoff (Bolsenga and Herdendorf 1993).

Precipitation on the Lake Erie watershed contributes approximately the same amount of water into the lake as precipitation falling directly on the surface of the lake, however the watershed has a much larger surface area. Thus, if all the water that fell on the watershed ran into the lake, the runoff would contribute three times as much as precipitation over the lake. However, only about one-third of the rain

**TABLE 2-8. LAKE ERIE WATER LEVELS**

| | Maximum | | | | | Minimum | | | | | Mean | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IGLD 1985 | | LWD | | Year | IGLD 1985 | | LWD | | Year | IGLD 1985 | | LWD | |
| | ft | m | ft | m | | ft | m | ft | m | | ft | m | ft | m |
| January | 573.69 | 174.86 | 4.49 | 1.37 | 1987 | 568.27 | 173.21 | -0.28 | -0.93 | 1935 | 570.80 | 173.98 | 1.60 | 0.49 |
| February | 573.43 | 174.78 | 4.23 | 1.29 | 1987 | 568.18 | 173.18 | -0.31 | -1.02 | 1936 | 570.77 | 173.97 | 1.57 | 0.48 |
| March | 573.75 | 174.88 | 4.55 | 1.39 | 1986 | 568.24 | 173.20 | -0.29 | -0.96 | 1934 | 571.03 | 174.05 | 1.83 | 0.56 |
| April | 574.08 | 174.98 | 4.88 | 1.49 | 1985 | 568.83 | 173.38 | -0.11 | -0.37 | 1934 | 571.56 | 174.21 | 2.36 | 0.72 |
| May | 574.05 | 174.97 | 4.85 | 1.48 | 1986 | 569.03 | 173.44 | -0.05 | -0.17 | 1934 | 571.82 | 174.29 | 2.62 | 0.80 |
| June | 574.28 | 175.04 | 5.08 | 1.55 | 1986 | 569.06 | 173.45 | -0.04 | -0.14 | 1934 | 571.92 | 174.32 | 2.72 | 0.83 |
| July | 574.25 | 175.03 | 5.05 | 1.54 | 1986 | 569.06 | 173.45 | -0.04 | -0.14 | 1934 | 571.88 | 174.31 | 2.68 | 0.82 |
| August | 573.95 | 174.94 | 4.75 | 1.45 | 1986 | 569.00 | 173.43 | -0.06 | -0.20 | 1934 | 571.65 | 174.24 | 2.45 | 0.75 |
| September | 573.59 | 174.83 | 4.39 | 1.34 | 1986 | 568.83 | 173.38 | -0.11 | -0.37 | 1934 | 571.39 | 174.16 | 2.19 | 0.67 |
| October | 573.95 | 174.94 | 4.75 | 1.45 | 1986 | 568.57 | 173.30 | -0.19 | -0.63 | 1934 | 571.06 | 174.06 | 1.86 | 0.57 |
| November | 573.65 | 174.85 | 4.45 | 1.36 | 1986 | 568.24 | 173.20 | -0.29 | -0.96 | 1934 | 570.83 | 173.99 | 1.63 | 0.50 |
| December | 573.82 | 174.90 | 4.62 | 1.41 | 1986 | 568.21 | 173.19 | -0.30 | -0.99 | 1934 | 570.80 | 173.98 | 1.60 | 0.49 |
| MEAN | 573.84 | 174.92 | 4.67 | 1.43 | | 568.63 | 173.32 | -0.17 | -0.57 | | 571.29 | 174.13 | 2.09 | 0.64 |

Period of Record:
1918-1996

Data Source:
U.S. Army Corps of Engineers, Detroit, MI, *Monthly Bulletin of Lake Levels for the Great Lakes.*

falling on the watershed makes its way to the lake. The rest is lost to the air by evaporation from the soil or by transpiration from plants.

### Wind Tides and Seiches

Wind tide or storm surge is a rapid rise in lake level resulting from the forced movement of surface water under the stress of wind. Once the wind has abated, the free oscillation (or sloshing) of the lake's surface is known as a seiche. Wind tide and seiche activity at Kelleys Island can raise and lower the water level as much as 3 to 7 ft (1 to 2 m) or more in a single storm, but typical daily fluctuations are in the range of 0.3 to 0.7 ft (0.1 to 0.2 m). Seiches are an important factor in producing short-period water level oscillations in Lake Erie at Kelleys Island. Owing to the orientation of the lake (longitudinal axis which nearly corresponds to the direction of the prevailing winds), the most common seiche is longitudinal and has a period of approximately 14 hours. Because of the island's position at the western end of Lake Erie, the magnitude of the fluctuations are more pronounced than those in the central part of the lake.

Oscillation in lake level may also be set up by elevated atmospheric pressure bearing down upon a particular region of the lake or by a low pressure cell passing over the lake. Once the high or low pressure cell has passed, water either surges back or streams away in the process of reestablishing equilibrium, and exhibits the oscillatory movement of a seiche. A particularly intense cyclonic storm passed over Lake Erie in January 1978, when the lake was significantly ice covered. The low pressure cell crossed the lake from south to north near Lorain, Ohio, inducing a noticeable water level rise (0.7 ft or 0.2 m) of a type that is rare for Lake Erie and usually only seen along the ocean coasts in response to hurricanes. The ensuing storm surge produced a 10-ft (3-m) difference in lake level between Marblehead, Ohio and Buffalo, New York, at the eastern end of the lake. Buffalo was flooded while Lorain reported a severe shortage of water at its treatment plant intake (Herdendorf et al. 2004).

### Lake-Flooding Potential

The U.S. Army Corps of Engineers (1977), in conjunction with the Federal Insurance Administration, developed a procedure for establishing flooding potentials for the open coast of Lake Erie using the 1% value from a frequency curve of the maximum instantaneous high level each year. This level is comparable to the storm water level which results from a wind setup superimposed on the undisturbed water level of the lake, but does not include wave runup caused by waves rushing up the beach or a shore structure. Water level records from 1899 to 1974 were used to calculate the flooding potential for 24 reaches of the Lake Erie coast. The coast of Kelleys Island, Ohio lies within reach "X." Open-coast flood levels were derived for 10-, 50-, 100-, and 500-year return periods; which represent the highest water levels along the coast that on the average will have a 10%, 2%, 1%, and 0.2%, respectively, chance of being equaled or exceeded in any given year. The predicted elevations for Long Point of Kelleys Island are presented in Table 2-9.

### Shore Erosion and Recession

The Kelleys Island shoreline is the best protected reach of Lake Erie in Erie County, Ohio—afforded by the natural rockbound shore, which markedly resists wave erosion. Investigations by the Ohio Division of Geological Survey have shown that the shape of Long Point has stayed the same since 1877 (Carter and Guy 1980). Recession, the landward movement of the shore, was found to have a very slow rate for Long Point, less than 1 ft (0.3 m) per year. Although the shore is relatively stable, wave attack is the most important erosion process at Long Point. Here, waves have sculptured table-rock features (Figure 2-14) and dislodged slabs of limestone weighing tons, stacking them along the shore (see Appendix D).

**TABLE 2-9. FLOODING POTENTIAL OF THE LAKE ERIE COAST AT LONG POINT, KELLEYS ISLAND, OHIO**

| Return | + MLS 1929[1] | | + IGLD 1955[2] | | + IGLD 1985[3] | | + LWD[4] | | + Mean[5] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Period | ft | m | ft | m | ft | m | ft | m | ft | m |
| 10-year | 576.3 | 175.66 | 574.8 | 175.20 | 575.4 | 175.38 | 6.2 | 1.89 | 4.1 | 1.25 |
| 50-year | 577.2 | 175.93 | 575.7 | 175.47 | 576.3 | 175.66 | 7.1 | 2.16 | 5.0 | 1.52 |
| 100-year | 577.5 | 176.02 | 576.0 | 175.56 | 576.6 | 175.75 | 7.4 | 2.26 | 5.3 | 1.62 |
| 500-year | 578.2 | 176.24 | 576.7 | 175.78 | 577.3 | 175.96 | 8.1 | 2.47 | 6.0 | 1.83 |

Notes:

1. Mean Sea Level 1929 (New York City mean tide level).
2. International Great Lakes Datum 1955 (Father Point, Quebec mean water level).
3. International Great Lakes Datum 1985 (Rimouski, Quebec mean water level).
4. Low Water Datum (LWD) = NOAA/USACE Chart Depth:
   LWD referred to MLS 1929 = 570.1 ft (173.8 m)
   LWD referred to IGLD 1955 = 568.6 ft (173.3 m)
   LWD referred to IGLD 1985 = 569.2 ft (173.5 m).
5. Mean Water Level = 2.1 ft (0.64 m) above LWD.
6. Ordinary High Water Mark (OHWM) = 4.2 ft (1.28 m) above LWD.

Data Source: U.S. Army Corps of Engineers (1977).

*Figure 2-14. Table Rock at the northern tip of Long Point, ca. 1960. Erosion of the pedestal has since resulted in the collapse of the table top (courtesy* Port Clinton Herald).

## Biota

### Wetlands

Along the eastern edge of the property, east of Long Point Lane, a number of vernal pools of standing water were noted in May, particularly due to the exceptionally wet spring in 2004. The pools occur on poorly-drained hydric (wetland-type) Millsdale silty clay loam soil. However, these wet areas did not then exhibit herbaceous or woody plants typical of wetlands. To be a jurisdictional (federally-controlled) wetland, three parameters must all be satisfied: (1) standing water or water saturated soil, (2) hydric soils, and (3) aquatic macrophytes (wetland plants). By June 8, 2004, all of the pools on the tract had dried up. Thus, these temporarily wet areas did not appear to be sustained long enough to foster aquatic plants and thus, would not be classified as wetlands. However, farther to the east, on Cleveland Museum of Natural History property, the pools are deeper, support sedges, and may experience saturated conditions long enough to fall in the wetlands category.

On June 28, 2004, an additional visit to the site revealed that the sedges in the vernal pools area had matured to the point where a positive identification could be made as *Carex frankii* (Frank's sedge). Although there are some 140 species of the genus *Carex* growing in Ohio (Braun 1967), *C. frankii,* is one of the most easily recognized species (Figure 2-15) by its crowded, more or less pistillate spikes (non-pollen, seed-producing structures) bristling with the long awns (slender bristle-like structure) of the scales. Reed (1988:23) classifies *Carex frankii* as a wetland obligate plant, indicating that this species "occurs almost always (estimated probability >99%) under natural conditions in wetlands." This coupled with the hydric nature of the soil, Millsdale silty clay loam (Robbins et al. 2002:175) and the presence of standing water or the water table with 0.5 ft (0.15 m) of the surface for one week or more during the growing season meets the 3-part federal criteria for classification as a jurisdictional wetland (Wetland Training Institute 1989). The boundary of the wetland area is delineated on Figure 2-16. Photographs of the vernal pools wetland are included in Appendix A where they are designated by the prefix WL. The orientation of the photographs is indicated on Figure 2-16.

Permanent or periodic inundation, or soil surface saturation with water to the surface, at least seasonally, are the driving forces behind wetland formation. The presence of water for a week or more during the growing season typically creates anaerobic conditions in the soil, which affects the types of plants that can grow and the types of soil that develop. All plants growing in wetlands have adapted in one way or another to life in permanently or periodically inundated or saturated soils. Such plants known as macrophytic hydrophytes, are capable of growing in water, soil, or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content. Hydric soils are defined as soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part, usually 7 days or more when soil temperatures are above 41°F (Wetland Training Institute 1989).

### Flora

**Upland Vegetation.** The interior portion of the Predevelopment, Ltd. property is completely forested except for the access road and utility right-of-way. The nearly level topography is characterized by a young forest in which the typical trees are short, less than 40 ft (12 m) tall, and small in diameter, less than 10 in (25 cm) breast high diameter (bhd). Review of Ohio Department of Natural Resources aerial photographs for the last half century indicates that the Predevelopment, Ltd. tract has been a vacant woodland throughout this period. The forest is dominated by hackberry (*Celtis occidentalis*), sugar maple (*Acer saccharum*), shagbark hickory (*Carya ovata*), and Ohio buckeye (*Aesculus glabra*) trees with a dense understory of garlic mustard (*Alliaria petiolata*), sweet cicely (*Osmorhiza longistylis*), and fleabane (*Erigeron philadelphicus*). Table 2-10 presents a list of the common plant species found on the Building Envelope and in the vicinity of the historic structures.

**Alvar Habitat.** The North Shore (near North Bay quarry) and Long Point shores of Kelleys Island consist of shelving bedrock and limestone cliffs. This type of landform is known as an *alvar*—a horizontal limestone terrain, laid bare by glacial action, which is maintained as a natural opening by constant waves and ice scour, and characterized by rare plants capable of coping with this harsh environment (Cusick 1997). Two Ohio endangered plant species, northern bog violet (*Viola nephrophylla*) and smooth rose (*Rosa blanda*), and two threatened Ohio plant species, balsam squaw-weed (*Senecio pauperculus*) and southern hairy rock cress (*Arabis hirsta* var. *adpressiplis*), are found on the

**TABLE 2-10. LIST OF PLANTS FOUND IN THE VICINITY OF THE BUILDING ENVELOPE AND HISTORIC SITES ON THE PREDEVELOPMENT, LTD. PROPERTY, LONG POINT, KELLEYS ISLAND, OHIO**

| WOODY PLANTS | COMMON NAME | IMAGE No(s) |
|---|---|---|
| ***Acer saccharum*** | **Sugar maple** | 2778 |
| ***Aesculus glabra*** | **Ohio buckeye** | 2969 |
| ***Carya ovata*** | **Shagbark hickory** | |
| ***Celtis occidentalis*** | **Northern hackberry** | 2778 |
| *Cornus amomum* | Silky dogwood | 2813 |
| *Cornus drummondii* | Rough-leaved dogwood | 2836, 2952 |
| *Fraxinus pennsylvanica* | Green ash | 2943 |
| *Populus deltoides* | Cottonwood | 2862 |
| | | |
| HERBACEOUS PLANTS | | |
| ***Alliaria petiolata*** | **Garlic mustard** | 2777, 2876 |
| *Allium cernuum* | Nodding wild onion | 2981 |
| *Carex frankii* | Frank's sedge | |
| *Carex granularis* | Meadow sedge | 2939 |
| ***Dactylis glomerata*** | **Orchard grass** | 2875, 2877, 2970 |
| *Duchesnea indica* | Indian strawberry | 2975, 2976 |
| ***Erigeron philadelphicus*** | **Philadelphia fleabane** | 2869, 2955, 2968 |
| *Galium mollugo* | White bedstraw | 2925 |
| *Geum canadense* | White avens | 2868 |
| *Hemerocallis fulva* | Orange day-lily | |
| *Hypericum perforatum* | Common St. John's-wort | |
| *Medicago lupulina* | Black medick | 2818, 2842, 2872 |
| *Nepeta cataria* | Catnip | |
| *Oxalis stricta* | Yellow wood-sorrel | 2871 |
| ***Osmorhiza longistylis*** | **Smooth sweet cicely** | 2966 |
| *Penstemon hirsutus* | Hairy beard-tongue | 2870 |
| ***Rhus radicans*** | **Poison ivy** | 2821 |
| *Rubus allegheniensis* | Common blackberry | 2851 |
| ***Solidago canadensis*** | **Canada goldenrod** | 2870, 2971 |
| *Sorghum halepense* | Johnson grass | 2971 |
| *Syringa vulgaris* | Lilac | 2838 |
| *Taraxacum officinale* | Dandelion | 2874 |
| *Verbascum thapsus* | Common mullein | 2822, 2875, 2940 |
| *Vinca minor* | Common periwinkle | 2838 |

Notes:

The above list documents the common woody and herbaceous plant species which occur at the proposed building site and in vicinity of the Lincoln House foundation and the Lincoln Stone Wall on the Predevelopment, Ltd. property, Long Point, Kelleys Island, Ohio (May 29-June 8, 2004).

Dominant species are in bold typeface.

Image nos. refer to digital images in the EcoSphere Associates database.

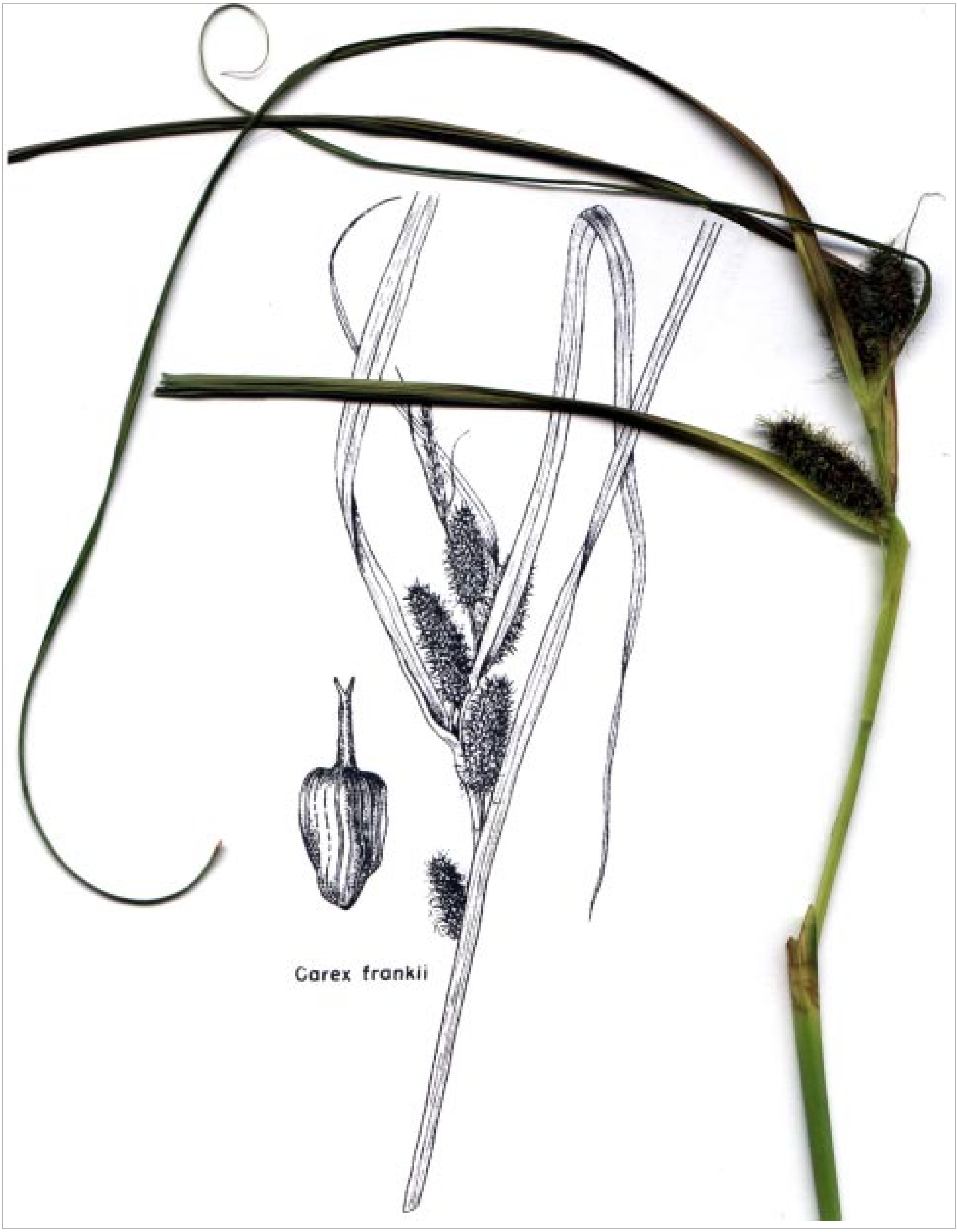


*Figure 2-15. The sedge,* Carex frankii, *an obligate wetland plant collected June 28, 2004 from a vernal pool at the eastern edge of the Predevelopment, Ltd. tract (illustration after Braun 1967).*

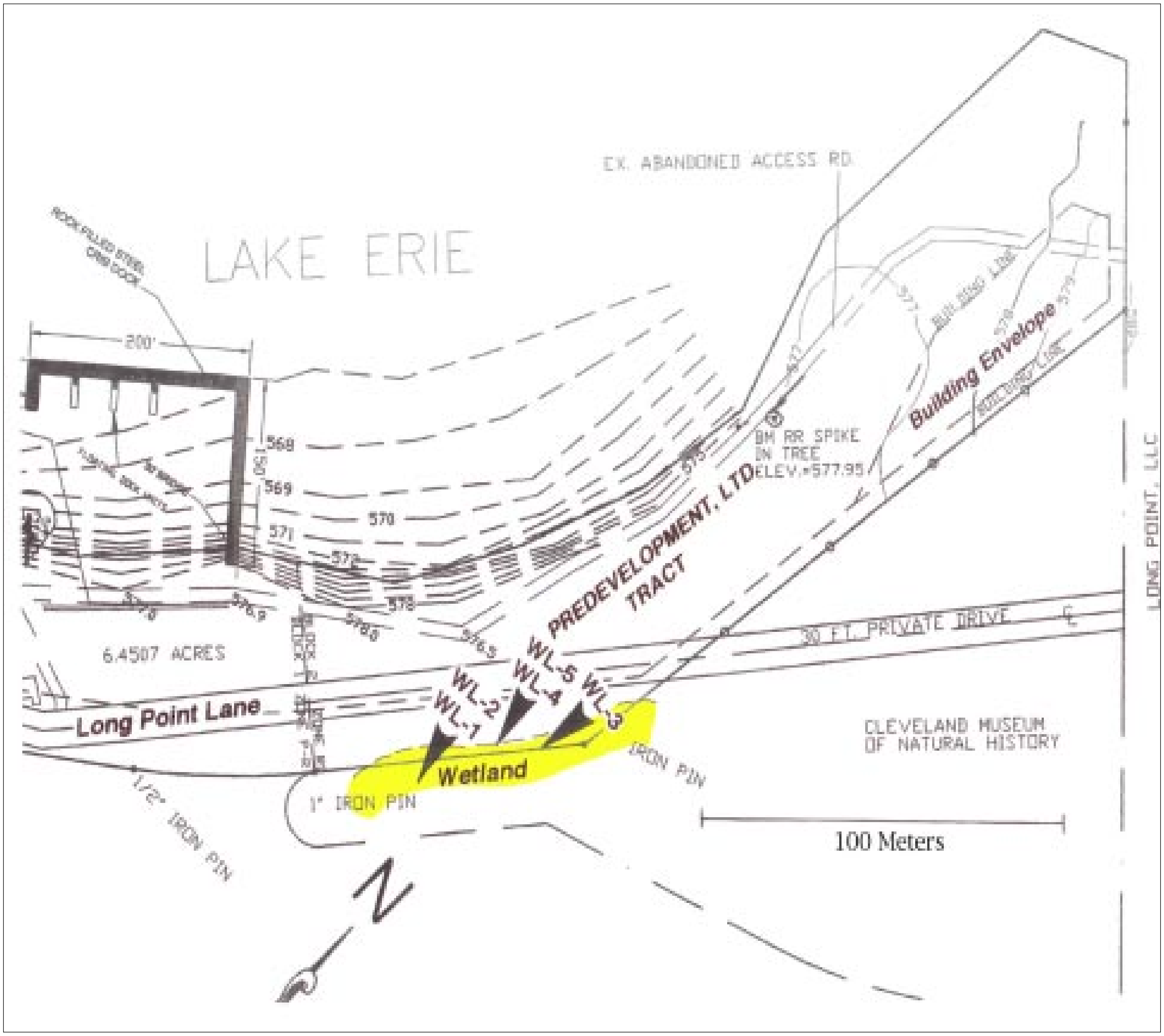


*Figure 2-16. Map of the northeastern portion of the Predevelopment, Ltd. tract, showing the location of the vernal pools wetland and Appendix A photographs.*

Kelleys Island alvars, often growing in a base that has been created by lichens and mosses. Table 2-11 presents a list of the shoreline plants identified from the North Shore alvar, while Table 2-12 contains a list of plants from the alvar shore of the Predevelopment, Ltd. property. All of the Predevelopment, Ltd. shoreline exhibits alvar characteristics. None the endangered or threatened species were found on the project property, but both *Rosa blanda* and *Arabis hirsta* var. *adpressiplis* occur on adjacent Cleveland Museum of Natural History property. The occurrence of these rare plants was confirmed with Kelleys Island specimens in the Museum's herbarium.

**Marsh Habitat.** Between the North Shore and Long Point alvar locations lays North Pond (Figure 2-2), a 36-acre (15-ha) marsh that occupies a depression underlain by the non-resistant Lucas Dolomite (about 1.2 mi or 2 km southwest of the Predevelopment, Ltd. tract). North Pond is separated from North Bay of Lake Erie by a barrier beach, but is open to the lake during periods of high lake levels and severe northeast storms. The marsh is a haven for migrating birds and home to the endangered aquatic plant, pond arrowleaf (*Sagittaria cuneata*).

**TABLE 2-11. LIST OF PLANTS FOUND ON THE NORTH SHORE ALVAR PRESERVE, KELLEYS ISLAND, OHIO**

| PLANT SPECIES | COMMON NAME | IMAGE No(s) | NOTE |
|---|---|---|---|
| *Achillea millefolum* | Yarrow | 2925, 2926 | no flower |
| *Allium cernuum* | Nodding wild onion | | |
| *Aquilegia canadensis* | Columbine | 2929 | in flower |
| *Carex eburnea* (?) | Bristle-leaved sedge | 2927 | in fruit |
| *Cornus amomum* | Silky dogwood | 2926 | |
| *Cornus drummondii* | Rough-leaved dogwood | | |
| *Erigeron philadelphicus* | Philadelphia fleabane | | in flower |
| *Euthamia graminifolia* (?) | Bushy goldenrod | 2927, 2936 | no flower |
| *Fragaria graminifolia* | Wild strawberry | 2925 | in flower |
| *Fraxinus pennsylvanica* | Green ash | | |
| *Galium mollugo* | White bedstraw | 2925 | in flower |
| *Geranium robertianum* | Herb Robert | 2928, 2929 | in flower |
| *Geum canadense* | White avens | 2936 | in flower |
| *Medicago lupulina* | Black medick | 2925 | yellow flower |
| *Morus rubra* | Red mulberry | 2931 | young fruit |
| *Penstemon hirsutus* | Hairy beard-tongue | | pale purple flower |
| *Physocarpus opulifoliuis* | Ninebark | 2923, 2933 | in bloom |
| *Populus deltoides* | Cottonwood | | |
| *Poa* sp. | Blue grass | 2930 | |
| *Rhus radicans* | Poison ivy | 2936 | |
| *Rubus allegheniensis (?)* | Common blackberry | 2930 | no fruit |
| *Salix amygdaloides* | Peach-leaved willow | | |
| *Solidago canadensis* | Canada goldenrod | 2929, 2936 | no flower |
| *Taraxacum officinale* | Dandelion | 2927, 2928 | in flower |
| *Viola nephrophylla* (?) | Northern bog violet | 2927 | in flower |
| Moss sp. | | 2928 | |
| Liverwort sp. | | 2928 | |

Notes:

The plants listed above were found growing along a side branch of the North Shore Loop Trail, which leads to the Lake Erie shore at the DNAP Alvar Preserve on Kelleys Island (May 29, 2004). This alvar habitat consists of exposed Columbus Limestone bedrock forming discontinuous ledges and large detached blocks with nearly horizontal surfaces 1 to 2 m above the lake surface (Image No. 2926). Many of the ledges are etched to low glacial grooves and striations (Image No. 2933). These bedrock benches are often backed by near vertical rock cliffs. This list is not inclusive and only includes plants identified from a cursory inspection.

**Aquatic Plants.** Aquatic botanists working in the Lake Erie islands region in the early 1900s (Pieters 1901) found that submerged plants occupied by far the largest segment of the aquatic vegetation. Although not as conspicuous as floating leaved plants (such as water lilies), submerged plants covered a greater area and comprised the bulk of the plant biomass. Up to the mid-1900s the bottoms of bays and inlets with water not over 10 ft (3 m) deep, were almost completely covered with vegetation (Core 1948). A dramatic decline in the abundance of these plants was noted in the 1960s and 1970s (Davis 1969, Stuckey 1971). When the lake once again cleared, as a result of phosphorus reduction and zebra mussel colonization,

**TABLE 2-12. LIST OF ALVAR PLANTS FOUND ON THE WEST SHORE OF LONG POINT, KELLEYS ISLAND, OHIO**

| DISTANCE(ft) (South to North from CMNH line) | PLANT SPECIES | COMMON NAME | IMAGE No(s)/NOTE |
|---|---|---|---|
| 0 | *Aquilegia canadensis* | Columbine | on bedrock |
| 10 | *Physocarpus opulifoliuis* | Ninebark | on bedrock |
| | *Geranium robertianum* | Herb Robert | on bedrock |
| 20 | *Juniperus virginiana* | Red cedar | 2848/small tree |
| 30 | *Tilia americana* | Basswood | in slab rock |
| 40 | *Ulmus americana* | American elm | |
| | [USFWS Lake Erie water snake protection sign on elm tree] | | |
| | *Geranium robertianum* | Herb Robert | large bed |
| 50 | *Osmorhiza longistylis* | Smooth sweet cicely | small white flowers |
| 60 | *Geranium robertianum* | Herb Robert | large bed |
| | *Prunus virginiana* | Choke cherry | small green fruit |
| 80 | *Fraxinus pennsylvanica* | Green ash | |
| 90 | *Melilotus albus* | White sweet clover | gravel bar; no flower |
| 120 | *Rhus typhina* | Staghorn sumac | hairy stem |
| 170 | *Ulmus americana* | American elm | |
| 190 | *Cornus amomum* | Silky dogwood | on gravel bar |
| 200 | *Acer saccharum* | Sugar maple | |
| 210 | *Alliaria petiolata* | Garlic mustard | 2777/one plant |
| 230 | *Populus deltoides* | Cottonwood | delta leaves |
| | *Rhus radicans* | Poison ivy | large bed |
| | *Parthenocissus inserta* | Thicket creeper | on gravel bar |
| 250 | *Prunus virginiana* | Choke cherry | |
| 310 | *Salix amygdaloides* | Peach-leaved willow | |
| 350 | *Populus deltoides* | Cottonwood | |
| 400 | *Aquilegia canadensis* | Columbine | on bedrock |
| | *Rubus allegheniensis* | Common blackberry | small plant |
| | *Penstemon hirsutus* | Hairy beard-tongue | pale purple flower |
| | *Geum canadense* | White avens | in flower |
| 430 | *Penstemon hirsutus* | Hairy beard-tongue | 2939 |
| | *Alliaria petiolata* | Garlic mustard | small white flowers |
| | *Carex granularis* | Meadow sedge | 2939 |
| 480-550 | *Syringa vulgaris* | Lilac | many bushes |
| 620 | *Verbascum thapsus* | Common mullein or Velvet-plant | 2940/flannelly<br>2941/old brown spike |
| 720 | *Tilia americana* | Basswood | 2942 |
| 760 | *Fraxinus pennsylvanica* | Green ash | 2943 |
| | *Taraxacum officinale* | Dandelion | |
| 780 | [fiberglass motorboat wreck on zebra mussel beach] | | 2771, 2944 |
| 820 | *Geum canadense* | White avens | in flower |
| 860 | *Aesculus glabra* | Ohio buckeye | small plant |
| 890 | *Lonicera japonica* | Japanese honeysuckle | in bloom |
| 900 | *Rosa multiflora* | Multiflora rose | 2945-7/white flower |
| 920 | *Geranium robertianum* | Herb Robert | large bed |
| 930 | *Morus rubra* | Red mulberry | 2948 |

**TABLE 2-12. LIST OF ALVAR PLANTS FOUND ON THE WEST SHORE OF LONG POINT, KELLEYS ISLAND OHIO (CONTINUED)**

| DISTANCE(ft) (South to North from CMNH line) | PLANT SPECIES | COMMON NAME | IMAGE No(s)/NOTE |
|---|---|---|---|
| 970 | *Salix exigua* | Sandbar willow | 2949 |
| 1020 | *Quercus macrocarpa* | Bur oak | 2950/small tree |
| 1030 | *Solidago* sp. | Goldenrod | 2951/purple stem |
| | *Cornus drummondii* | Rough-leaved dogwood | 2952 |
| 1060 | *Osmorhiza longistylis* | Smooth sweet cicely | 2953 |
| 1110 | *Prunus virginiana* | Choke cherry | 2954 |
| 1130 | *Populus deltoides* | Cottonwood | at waters edge |
| | *Rhus radicans* | Poison ivy | climbing cottonwood |
| | *Salix amygdaloides* | Peach-leaved willow | red young leaves |
| 1150 | *Physocarpus opulifoliuis* | Ninebark | no flowers |
| 1160 | *Cornus amomum* | Silky dogwood | 2813 |
| 1180 | *Erigeron philadelphicus* | Philadelphia fleabane | 2955, 2956 |
| 1200 | *Salix exigua* | Sandbar willow | 2957, 2959/in water |
| 1210 | *Juncus temuis* | Path rush | 2958-2960/in water |
| 1270 | *Mentha arvensis* | Field mint | 2961 |
| | *Melilotus albus* | White sweet clover | 2961/no flower |
| | *Geum canadense* | White avens | 2961/in flower |
| | *Medicago lupulina* | Black medick | 2961/yellow flower |
| 1300 | *Heuchera americana* | Alumroot | 2818/no flower |
| 1320 | *Physocarpus opulifoliuis* | Ninebark | 2813 |
| | *Acer saccharum* | Sugar maple | 2816 |
| | *Vitus riparia* | Riverbank grape | cobble beach |
| 1350 | *Juniperus virginiana* | Red cedar | 2962; young |
| 1430 | *Solanum dulcamara* | Bittersweet nightshade | 2963, 2964 |
| 1530 | *Impatiens capensis* | Jewelweed | 2965, 2966/young |
| | *Osmorhiza longistylis* | Smooth sweet cicely | 2966/no flower |
| 1580 | *Rhus radicans* | Poison ivy | large bed |
| 1600 | *Aesculus glabra* | Ohio buckeye | 2967/small tree |
| | [2 pink granite boulders (glacial erratics; 1-m dia) at tip of headlands] | | |

Notes:
The plants listed above were found growing within 20 ft of the Lake Erie waterline along a quarter-mile reach of the western shore of Long Point, Kelleys Island, Ohio (May 29, 2004). The reach begins at the northern boundary of the Cleveland Museum of Natural History property and continues to the north. This alvar-like habitat consists of exposed Columbus Limestone bedrock, including low ledges and shelving strata that slope gently lakeward (Image No. 2959), and beaches composed of limestone and glacial erratic pebbles, cobbles and boulders. One, 100-ft segment midway along the reach is composed primarily of zebra mussel shells and a light sand of shell fragments. The rock ledges along this reach are somewhat lower than the rock benches at the Alvar State Nature Preserve along the north shore at Kelleys Island State Park, and are not backed by near vertical rock cliffs as they are at the Preserve. Thus, ice scour may be greater along Long Point due to the lakeward sloping nature of the bedrock strata as compared to the elevated, nearly flat ledges at the Preserve. This potentially harsher environment may explain why some of the species noted on the Preserve alvar, such as northern bog violet (*Viola nephrophylla*), are absent from Long Point. Likewise, the presence of a greater variety of habitats on Long Point, such as gravel bars and sand beaches, may account for the greater variety of species noted there.

attached submerged plants once again became abundant in the nearshore water of the Lake Erie islands. By the mid-1990s most of the plant species reported by the early botanists had returned to the bays and protected shores (Stuckey and Moore 1995). Currently they are perhaps more abundant and growing at deeper depths than in the first half of the 20th century owing to the greater water clarity presently enjoyed by the lake.

In recent years the water clarity of western Lake Erie has improved to the point where sunlight now reaches to the crests of some of the reefs and the nearshore bottom with enough intensity to simulate the growth of submerged vascular (flowering) plants as well as algae. Off Kelleys Island, the attached green alga, *Cladophora glomerata*, is the dominant photosynthetic organism in the nearshore waters in late spring and early summer, followed by short blades of wild celery (*Vallisneria americana*) offshore. By August this algae diminishes in importance and is replaced by several species of submerged flowering plants that can be observed in water up to 10 or 15 ft (3 to 4.5 m) deep. Typically these plants grow attached to the bottom, but rarely protrude above the lake's surface. During the submerged cultural resources survey, relatively dense beds of *Cladophora glomerata* were noted in the nearshore regions were boulders and cobbles dominated the bottom material. Farther offshore, particularly on the cobble bottoms in the northern half of the study area, Sago pondweed (*Potamogeton pectinatus*) dominated, followed by patches of wild celery (*Vallisneria americana*), and coontail (*Ceratophyllum demersum*). Within the footprint of the proposed boat docking facility, no significant growths of vascular aquatic plants were noted; patches of *Cladophora glomerata* were observed on the cobble and boulder beds, generally in the zone from 25 to 75 ft offshore.

Offshore in North Bay, the bottom consists of silty sand mixed with gravel, limestone cobbles, and large glacial boulders. The shipwreck remains of the *ADVENTURE* and *W. R. HANNA* occur on this material. A thin layer of zebra mussels (*Dresissena polymorpha*) and quagga mussels (*Dresissena bugensis*) have colonized most of the exposed surfaces of the wrecks, and small freshwater sponges (*Eunapius fragilis*) in cracks and crevices. Patches of wild celery (*Vallisneria americana*) and coontail (*Ceratophyllum demersum*) abound at the sites, most of it 3 to 5 ft (1 to 1.5 m) tall in late summer, as well as some thin growths of attached green algae (*Cladophora glomerata*).

In protected areas around the Lake Erie islands wild celery can form dense beds out to a depth of 8 ft (2.4 m), up to 500 ft (150 m) offshore with occasional open areas within these beds. Other aquatic plants which are frequently associated with wild celery include water-milfoil (*Myriophyllum spicatum*), sago pondweed (*Potamogeton pectinatus*), small pondweed (*Potamogeton pusillus*), and curly pondweed (*Potamogeton crispus*). A study off the southeastern shore of Middle Bass Island in 1998 showed that beyond 500 ft (150 m) offshore, wild celery is much less abundant and is replaced by Richardson's pondweed (*Potamogeton richardsonii*) and water star-grass (*Heteranthera dubia*); these plants can dominate to a depth of 12 ft (3.7 m) at some 800 ft (240 m) offshore (Herdendorf 1998).

## FAUNA

**Terrestrial Animals.** Sightings of avifauna and land animals on Kelleys Island include the following number of species: 241 birds, 78 spiders, 45 butterflies, 26 dragonflies, 15 mammals, 9 snails, 6 snakes, and 4 amphibians (Cooper and Herdendorf 1977, Herdendorf 1982). Long Point supports a number of birds during spring and fall migrations as they use the Lake Erie islands as stepping stones in their crossing of the lake. White-tailed deer (*Odocoileus virginianus*) is an abundant mammalian species on the island, with a herd of approximately 10 individuals being observed near the base of Long Point on June 3, 2004. The skull of a coyote (*Canis latrans*) was found at the surface of a test pit at the Lincoln House Site on May 29, 2004.

Five species federally listed as endangered or threatened and a federal candidate species are known to occur in Erie County, Ohio:

| | |
|---|---|
| Lake Erie watersnake (*Nerodia sipedon insularum*) | Threatened |
| Great Lakes piping plover (*Charadrius melodus*) | Endangered |
| Indiana bat (*Myotis sodalis*) | Endangered |
| Lakeside daisy (*Hymenoxys herbacea*) | Threatened |
| Bald eagle (*Haliaeetus leucocephalus*) | Threatened |
| Eastern massasauga rattlesnake (*Sistrurus catenatus*) | Candidate |

Of the federally-listed and candidate species that occur in the Erie County, only the Lake Erie watersnake and lakeside daisy are known to occur on Kelleys Island. The lakeside daisy occurrence is a reintroduced population within an abandoned quarry owned by the State of Ohio, approximately 1.5 mi (2.4 km) southwest of the Predevelopment, Ltd. tract.

**Lake Erie Watersnake (*Nerodia sipedon insularum*).** The rocky shores of Kelleys Island and the nearshore waters of Lake Erie are home to this federally threatened reptile. This watersnake was listed as threatened under the U.S. Endangered Species Act in fall 1999 and endangered in the State of Ohio in spring 2000. Dr. Richard B. King (Northern Illinois University, Department of Biological Sciences) has conducted censuses of the Lake Erie watersnake population on Kelleys Island since 1980 based on mark-recapture methods (King 2004). The most recent estimates for adults at several locations on the island are listed below:

| Shore Location | Mean Length (km) | Population | Density (adults/km) |
|---|---|---|---|
| Long Point | 2,750 | 124 | 45 |
| Marina (Seaway) | — | 106 | — |
| Minshall (Northwest Shore) | 450 | 87 | 60 |
| South Shore | 680 | 802 | 1,179 |
| Southeast Shore | 1,000 | 414 | 414 |

These data indicate that the Long Point shore is apparently the least preferred habitat for Lake Erie watersnakes of those studied on the island. This is significant because human-related disturbances are extremely low on Long Point. The watersnake population density is only 4% of that along the south shore where human disturbances are likely the highest on Kelleys Island. The watersnake population on Long Point has been very stable for the past two decades, averaging 44 adults/km in the early 1980s and 45 adults/km in the early 2000s (King 2004).

Of 142 individual prey items recovered from neonate, juvenile, and adult Lake Erie watersnakes, more that 92% were round gobies (*Neogobius melanostomus*), an invasive fish species that first appeared in Lake Erie in the mid-1990s. The introduction of the round goby, and its emergence as a primary food source, correlate with an increase in adult and neonate body size and growth rate, which may help conserve this threatened snake (Ray 2004). These snakes were occasionally observed fishing for yellow perch, round gobies, and other species in North Bay during the submerged cultural resources survey.

**Aquatic Animals.** In addition to the zebra mussels and freshwater sponges mentioned above, many other bottom-dwelling invertebrates are found within the lake. Other noteworthy members of the bottom fauna commonly observed by divers on rock or gravel, especially areas with aquatic vegetation, include the rusty crayfish (*Orconectes*), busy sideswimmers (*Gammarus*), and several species of caddiflies (Trichoptera). On sandy bottoms, the once common freshwater clams are greatly diminished, but occasionally observed. One species is particularly fascinating; the female pocket-book or fatmucket clam (*Lampsilis ventricosa*) is capable of extending and pulsating its mantle in such a way as to resemble an injured minnow. This activity attracts fish species such as bluegill, yellow perch, and smallmouth bass, which increases the opportunity for juvenile clams (glochidia) to attach themselves to a host fish after they have been ejected from the parent. The larvae are released by the parent when its light sensitive spots are stimulated, such as by the shadow of a passing fish. The pollution sensitive mayfly (*Hexagenia*) has made a remarkable recovery in recent years. These burrowing mayflies are native to western Lake Erie and were abundant until the early 1950s when they disappeared for 40 years as a result degraded water and sediment quality. Nymphs are now recolonizing the mud bottoms in the Islands Region, but the soft bottoms of the lake continue to be dominated by less sensitive organisms, including red worms (oligochaetes) and midge larvae (chironomids).

The Lake Erie islands are utilized as a route and stopover site by waterfowl, shorebirds, raptors, and passerine (perching) birds. Mallards (*Anas platyrhynchos*), black ducks (*Anas rubripes*), and blue-winged teal (*Anas discors*) breed in nearby marshes. Sizable populations of great blue herons (*Ardea herodias*), great egrets (*Ardea albus*), black-crowned night-herons (*Nycticorax nycticorax*), double-crested cormorants (*Phalacrocorax auritus*), and several gulls (*Larus* spp.) have established rookeries and nesting sites on the Sister Islands to the west of Kelleys Island (Herdendorf 1984).

Western Lake Erie, and in particular the Islands Region, has long been considered the most valuable fish spawning and nursery area in the lake. At least 95 species of fish have been reported from the waters surrounding the Lake Erie islands. This diversity and abundance of fishes can be attributed to: (1) southernmost (warmest) position in relation to the other Great Lakes, (2) shallow, nutrient rich waters, and (3) variety of aquatic habitats, especially the rocky reefs and adjacent coastal wetlands. Many of the predator fish species of the Islands Region, particularly walleye (*Sander vitreus*), smallmouth bass (*Micropterus dolomieui*), and white bass (*Morone chrysops*), rely on sight to find their prey. Efficient sight feeding, especially for large fish seeking moving prey, requires clear water to discern their prey at relatively long distances. The clear water found over the reefs and shoals provides such conditions. Reefs also foster beds of aquatic plants and attached green algae, such as *Cladophora*, which harbor emerging insects and small crustaceans which attract small fish, usually shiners (*Notropis* spp.), upon which walleye prey (Herdendorf 1980).

Research divers in western Lake Erie have reported walleyes lying motionless on rocky bottoms during daylight hours. This daily “resting requirement” also tends to concentrate walleye around the reefs and shoals. The deeper mud bottoms with higher organic contents typically have lower oxygen levels. This is especially true during calm periods when currents and water mixing are diminished. Walleyes appear not to prefer mud bottoms as resting areas because of the lower oxygen concentration found there. Walleyes commonly spawn over rock, rubble, or gravel in streams tributary to large lakes, but in Lake Erie major spawning grounds occur on the reefs and shoals. These rocky projections are swept free of mud by breaking waves, which might otherwise smother spawned eggs. Waves and currents acting on the reefs also simulate the riffle habitat, which may serve to attract walleyes. Once spawning begins on a particular reef, fry imprinting would favor continued utilization of the reef by returning walleye populations (Herdendorf 1980).

The fisheries resources are abundant in the waters surrounding Kelleys Island with some 25 species of fishes commonly present in the North Bay (Table 2-13). Recent electrofishing surveys by Ohio EPA (Thoma 1997) in the nearshore waters at North Bay quarry dock and Long Point (both on the north side of Kelleys Island) indicate a greater than average number of species (16.8 versus 15.3) and a higher than average density of fish (317 versus 252 per 500 m) when compared with all other sampling stations in the Lake Erie islands. Thoma (1997) found smallmouth bass (*Micropterus dolomieui*) in greater densities off Long Point than anywhere else in the islands (up to 63 individuals per 500 m). Several fish species frequent the shipwreck sites, which attracts fishermen to these sites. The round goby (*Neogobius melanostromus*) was the most frequently observed fish species during the underwater cultural resources survey, followed by common carp (*Cyprinus carpio*) and smallmouth bass (*Micropterus dolomieui*).

## Hazardous Materials

In the course of traversing the Predevelopment, Ltd. property on Long Point, a special effort was made to identify and document hazardous waste materials. A dense exploratory pattern was conducted within the Building Envelope (10-m grid). Throughout the remainder of the tract, the pattern was sufficient to provide a comprehensive visual inspection of all land and submerged areas. These inspections revealed a relatively pristine environment, remarkably free of anthropogenic debris and no evidence of toxic, radiological, or otherwise hazardous materials. The lack of hazardous materials is consistent with data on the historic usage of the property on Long Point (see Chapter 4).

Offshore, the only navigational hazard noted was the shipwreck of the steambarge *ADVENTURE*. The timbers, engine works, and propeller of this wreck lie at a depth of less than 5 ft (1.5 m) under typical lake conditions. During periods of low lake levels, storm surges, and seiches portions of the wreck can be exposed and cause minor ice pile-ups in winter (Figure 2-17).

**TABLE 2-13. COMMON FISHES OF THE KELLEYS ISLAND REGION OF LAKE ERIE**

| Common Name (Scientific Name) | Bottom species | Plant-habitat species | Sensitive species | Tolerant species | Open-lake species | Non-indigenous species |
|---|---|---|---|---|---|---|
| Gizzard shad (*Dorosoma cepedianum*) | | | | | X | X |
| Goldfish (*Carassius auratus*) | | | X | X | | |
| Common carp (*Cyprinus carpio*) | | | X | | X | |
| Carp x Goldfish (hybrid) | | | | X | X | |
| Emerald shiner (*Notropis atherinoides)* | | | | | X | |
| Spottail shiner (Notropis hudsonius) | | | | | X | |
| Mimic shiner (*Notropis volucellus*) | | | X | | | |
| Shorthead redhorse (*Moxostoma macrolepidotum)* | | | X | | | |
| Brown bullhead (*Ameiurus nebulosus)* | X | | | X | | |
| Channel catfish (*Ictalurus punctatus*) | X | | X | | | |
| Stonecat madtom (*Noturus flavus*) | | | X | | | |
| Brook silverside (*Labidesthes sicculus)* | | | X | | | |
| White perch (*Morone americana)* | | | | X | X | |
| White bass (*Morone chrysops*) | | | | | X | |
| Rock bass (*Ambloplites rupestris*) | | | | | X | |
| Pumpkinseed sunfish (*Lepomis gibbosus*) | X | | | | | |
| Bluegill (*Lepomis macrochirus*) | | X | | | X | |
| Smallmouth bass (*Micropterus dolomieui*) | | | | | X | |
| Largemouth bass (*Micropterus salmoides*) | | X | | | | |
| Greenside darter (*Etheostoma blenniodes*) | X | | | | | |
| Fantail darter (*Etheostoma flabellare*) | X | | | | | |
| Yellow perch (*Perca flavescens*) | X | X | | | X | |
| Logperch (*Percina caprodes*) | X | | | | | |
| Walleye (*Sander vitreus*) | | | | | X | |
| Freshwater drum (*Aplodinotus grunniens*) | | | | | X | |
| Round goby (*Neogobius melanostromus*) | X | | | X | X | |
| Mottled sculpin (*Cottus bairdi*) | X | | | | X | |

*Figure 2-17. Exposed timbers of the steambarge* ADVENTURE *shipwreck during a low water storm in the winter of 1964 (courtesy of Russell Matso).*